Thesis Submitted for the Degree of Doctor of Philosophy

An archaeobotanical investigation of plant use, crop husbandry and animal diet at early-mid Neolithic Çatalhöyük, Central Anatolia

Student: Dragana Filipović

Thesis supervisor: Dr Amy Bogaard

Examiners:
Dr Rick Schulting
Professor Dorian Fuller

Wolfson College and
The Institute of Archaeology
University of Oxford

Trinity Term 2012

An archaeobotanical investigation of plant use, crop husbandry and animal diet at early-mid Neolithic Çatalhöyük, Central Anatolia

Thesis Submitted for the Degree of Doctor of Philosophy

Student: Dragana Filipovic
Supervisor: Dr Amy Bogaard
Examiners: Dr Rick Schulting and Professor Dorian Fuller
Wolfson College and the Institute of Archaeology, University of Oxford
Trinity Term 2012

Abstract

The aim of this project is to produce new archaeobotanical evidence for the early-mid Neolithic sequence of Çatalhöyük in Central Anatolia, and use it as a basis for investigation into the nature and scale of crop husbandry at a long-living early farming settlement in south-west Asia. The archaeobotanical weed record is here considered the primary source of information on the aspects of crop husbandry indicative of different cultivation practices (i.e. permanence, seasonality and intensity) and crucial for distinguishing between contrasting agricultural systems (i.e. intensive *vs*. extensive cultivation)

Of the thousands of archaeobotanical samples available from the study site, 115 samples from the early-mid Neolithic occupation were selected as archaeobotanically rich and originating from archaeologically well-defined situations ('primary deposits'). Crop remains dominate the selected dataset and it is suggested that crop processing is one of the major source of the material. Another major taphonomic factor contributing to, and shaping the macro-botanical assemblage is burning of animal (sheep/goat) dung as fuel, as has been documented by micromorphological, and previous and current archaeobotanical analysis of macro-remains and phytoliths at the site. It has been proposed that residues from the two processes (crop processing and dung burning) are mixed in many archaeological deposits, obscuring the distinction between and impeding consideration of the two separate practices.

Various analytical approaches are applied and combined in order to 'disentangle' arable weeds from dung-derived taxa in the archaeological deposits. In order to determine the stage(s) of crop processing represented by the samples, ethnoarchaeological models and ethnographically-derived statistical methods for crop processing analysis are employed. The archaeobotanical criteria for identification of dung-derived material, supported by the ethnographic information, ecological data and observations from the sheep/goat feeding experiments, are used for recognition of the material arriving at the site via burning of dung. The variability in the assemblage is explored using the correspondence analysis; the patterning revealed the differences between arable weeds and wild taxa deriving from sheep/goat dung, enabling the clear separation of the two datasets.

The material identified as deriving from sheep/goat dung offers a basis for consideration of livestock diet, with wider implications for land use and integration with farming. The archaeobotanical weed data are compared on the basis of their ecological characteristics to the modern weed surveys and studies of traditional crop husbandry regimes. The results indicate that crops were grown in fixed plots sown in autumn and managed using intensive methods (e.g. careful tillage, weeding, manuring) implying close proximity of the fields to the settlement. The combined evidence from animal and crop husbandry suggests intensive garden cultivation as the most plausible model for early-mid Neolithic Çatalhöyük. The identified cultivation system has implications for issues such as settlement location, residents' mobility, crop cultivation productivity and long-term sustainability, as well as social context of farming possibly reflected in the settlement's spatial organisation.

Acknowledgements

It has been a tremendous fortune to have Dr Amy Bogaard as the supervisor. Her infinite help over the years, the continuous professional and personal support, advice, and guidance and, at times most valuable, understanding and patience received from her are most unique. Her encouragement and perseverance were crucial for finishing my thesis. I sincerely thank her for showing faith in an unproven aspirant from the Balkans and securing funding for my project. Hers and the help from her family in numerous situations (from archaeology-related to logistic support and base) are greatly appreciated.

I am deeply indebted to Mike Charles and Glynis Jones, my external advisers at Sheffield University, for their professional expertise and much help at critical stages of my research. Many other colleagues provided valuable information, to name a few: Sue Colledge, Füsun Ertuğ, Mark Nesbitt, Shahina Farid, John Hodgson, Nick Fieller, Andrew Fairbairn, and Christine Hastorf. I am grateful to everyone on the Çatalhöyük teams, especially to Mirjana Stevanović who invited me to join the excavations in the BACH Area back in 2001. A special thank-you to the team-members who provided access to unpublished/in press data - Ruth Tringham, Chris Doherty, Eleni Asouti, Liz Henton, Michael Wallace, Müge Ergun, Flip Ryan.

I was lucky to have conducted (most of) my research at the Institute of Archaeology in Oxford, where I took part in setting up the archaeobotanical laboratory at the Donald Baden-Powell Quaternary Research Centre; I thank Nick Barton for letting me use the space. I am also grateful to Rick Schulting and Mark Robinson who assessed my work along the way and provided extremely useful advice. I am indebted to Ian Cartwright for photographing the plant material. In Sheffield thanks are also due to Catherine Longford for being my host and a guide during the study-visits, and arranging access to the Biomedical Unit and the scanning electron microscope.

I am particularly grateful to my wonderful friends for their patience and good spirit. Rebecca Fraser never held back, always 100% there to support, offer advice, listen, and help. Linda Fibiger's common sense and down-to-earth attitude has helped me stay (more-or-less) sane and not to lose hope - thanks for everything! I also thank Alex Livarda, Müge Ergun, Ian Cartwright, and Sun-woo Kim. A heartfelt thank you to the colleagues at Nottingham University, especially Sera Baker, who helped me get used to the new living and working environment. In Oxford I am indebted to Paul Kostich and his family for helping me and my family settle in.

None of this would have been possible without my extended family who never failed to inspire me. I am grateful to my daughter Nadja for adding another aspect to my PhD-life and helping me stay in touch with (her) reality. I thank my parents and my husband for their understanding and support throughout, and for not letting me give in. I apologise to everyone for the prolonged time I needed to complete the work - a huge thank you for your patience!

Table of contents

Abstract i

Acknowledgements iii

Table of contents iv

List of tables ix

List of figures xii

Chapter 1 **Introduction** **1**

1.1 Agricultural expansion and social change in Neolithic south-west Asia 1

1.1.1 The case of Çatalhöyük, Central Anatolia 4

1.1.2 The nature of agriculture in Neolithic south-west Asia 6

1.2 The present study 8

1.2.1 The issue of assemblage formation at Çatalhöyük 9

1.2.2 Arable and pastoral land use at Çatalhöyük 11

1.3 Thesis structure 12

Chapter 2 **Archaeological and environmental background** **14**

2.1 Archaeology 14

2.1.1 Location 14

2.1.2 Chronology and stratigraphy 16

2.1.3 History of excavation 20

2.1.4 Summary of archaeological features 22

2.2 Macro-botanical and faunal evidence 25

2.2.1 Previous archaeobotanical research at Çatalhöyük 25

2.2.2 Overview of the faunal assemblage 27

2.2.3 The evidence from the wider region 28

2.3 Environment 34

2.3.1 Present-day environment of Central Anatolia and the Konya plain 34
2.3.1.1 Climate 36
2.3.1.2 Soils 37
2.3.1.3 Vegetation 39
2.3.2 Early Holocene environment of Central Anatolia and the Konya plain 40
2.3.2.1 Climate and vegetation 42
2.3.2.2 Soils of the Çarşamba alluvial fan 44
2.3.2.3 Çatalhöyük vegetation reconstruction - archaeobotanical and wood charcoal record 48
2.3.2.4 Environment and agriculture at Çatalhöyük 51
2.3.2.5 Summary 56

Chapter 3 **Methodology** **58**
3.1 Field methods: sampling and flotation 58
3.2 Previous sample assessment and analysis 59
3.3 Selection of samples for the present study 61
3.3.1 Scanning 63
3.3.2 Archaeological context 64
3.3.2.1 Selected unit types 65
3.3.2.2 Summary of samples selected by unit types 70
3.3.3 Subsample study 72
3.4 Sorting of the selected samples 73
3.5 Identification 77
3.6 Quantification 79
3.6.1 Counting 79
3.6.2 Calculating the total number of items per sample 81
3.6.3 Amalgamation of taxa 82
3.6.4 Amalgamation of samples 87
3.7 Statistical data analysis 87
3.7.1 Discriminant analysis 87
3.7.2 Correspondence analysis 89
3.8 The use of ecological (and biological) data 91

Chapter 4 **Overview of the assemblage** **93**

4.1 Preservation 93

4.2 General sample composition 94

4.3 Crops 95

4.3.1 Cereals 95

4.3.2 Legumes 98

4.3.3 Classification of samples based on the crop content 103

4.3.4 Summary 107

4.4 Wild taxa 108

4.4.1 Fruits, nuts and tubers 108

4.4.2 Reed 110

4.4.3 Wild and/or weed taxa 111

4.5 Continuity in plant use over time 122

Chapter 5 **Formation of the assemblage** **125**

5.1 Sources of charred material at Çatalhöyük 126

5.2 Processes involved in the formation of the assemblage 127

5.2.1 Crop processing 127

5.2.1.1 Crop-based method of crop-processing analysis 130

5.2.1.2 Weed-based method of crop-processing analysis 131

5.2.2 Harvesting methods 133

5.2.3 Use of animal dung as fuel 135

5.2.4 Charring (carbonization) and the biases imposed 138

5.3 Crop processing stages represented in the Çatalhöyük samples 140

5.3.1 Crop processing analysis using the crop-based method 140

5.3.1.1 Hulled wheat 141

5.3.1.2 Free-threshing cereals 144

5.3.2 Crop processing analysis using the weed-based method 151

5.3.3 Synthesis of the results from crop processing analysis 156

5.4 Dung-derived plant material at Çatalhöyük 157

5.4.1 Presence of recognizable animal dung in archaeological deposits 158

5.4.2 The biology and ecology of non-crop (wild/weed) taxa 160

5.4.2.1 Habitat types 160

5.4.2.2 Flowering/fruiting time (seasonality) 161
5.4.2.3 Palatability 163
5.4.3 Behaviour of non-crop taxa in relation to crop processing 164
5.4.4 The relative proportions of crop types and plant parts (grain and chaff) 166
5.4.5 Summary of the identification of dung-derived material 168

Chapter 6 **Exploring variability across the assemblage 170**
6.1 Variation in the crop and wild content 170
6.1.1 Crop processing as a cause of variation 175
6.1.2 Ecological causes of variation 176
6.1.3 Archaeological context of the samples 178
6.2 Variation in the assemblage based on the wild content only 182
6.3 Summary and conclusions 185

Chapter 7 **Animal and crop husbandry at Çatalhöyük 187**
7.1 Arable *vs*. non-arable wild/weed evidence – a summary 187
7.2 Animal husbandry 188
7.2.1 Faunal and isotope evidence of sheep (and goat) herding 190
7.2.2 Evidence of sheep diet from the present study 193
7.2.2.1 Method and season of plant consumption 195
7.2.2.2 Life-cycle and habitat 197
7.2.3 Conclusions 200
7.3 Crop husbandry 202
7.3.1 Approaches to the study of crop production based on archaeobotanical weed evidence 203
7.3.2 The permanence of fields 208
7.3.3 Sowing time 215
7.3.4 The intensity and scale of arable production 220
7.3.5 Harvesting height and method, and the implications for animal diet and dung use 224
7.3.6 The location of arable fields 231
7.3.7 Cultivated land area and cereal yields 234

7.3.8 Conclusions 241

Chapter 8 **Conclusions: Plant use, crop husbandry and animal diet at early-mid Neolithic Çatalhöyük 243**

8.1 Addressing the research questions 243

8.1.1 Food or fuel? Taphonomic considerations 243

8.1.2 The nature and scale of crop cultivation 244

8.1.3 Animal (sheep/goat) diet and the use of dung 245

8.1.4 The plant assemblage from Çatalhöyük in its regional context 245

8.2 The socio-economic role of integrated mixed farming at Çatalhöyük 248

Tables and Figures 255

Bibliography 303

Appendices 331

Appendix 1 Fieldwork in Kastamonu region, North (Black Sea) Turkey 331

Appendix 2 Experimental measuring of 'winnowability' of wild seeds 336

List of tables

Table 2.1	Central Anatolian chronology	18
Table 2.2	Correlation between the two stratigraphic systems - Mellaart Levels and Hodder phases	19
Table 2.3	Summary of the subsistence evidence from Central Anatolian Neolithic sites	29
Table 3.1	Summary by context type of the samples with scanning scores '2' and '3' selected on archaeological grounds as potentially interesting	71
Table 3.2	Distribution of the selected samples and units across different archaeological contexts, structures and occupation phases of the East Mound	74
Table 3.3	Distribution of the selected samples across the sequences of buildings in the South and North (inc. BACH) excavation areas	75
Table 3.4	Fractions of the selected samples for which the item counts were calculated	82
Table 3.5	The initial and amalgamated (final) crop identifications	83-84
Table 3.6	The amalgamated (determinate and indeterminate) crop types	85
Table 3.7	Proportional re-assignment of indeterminate crop grain/seed	86
Table 3.8	Amalgamation of samples derived from the same unit	88
Table 4.1	Absolute and percentual representation of crop and wild material in the samples	256-257
Table 4.2	The overall abundance and frequency (ubiquity) of the ten crop types	96
Table 4.3	The abundance and ubiquity of the three crop groups	105
Table 4.4	Wild taxa	258-259
Table 4.5	Groups of wild taxa, their abundance and ubiquity	260-261
Table 4.6a	Frequent wild/weed taxa (indeterminate wild/weed excluded)	113
Table 4.6b	Rare wild/weed taxa (indeterminate wild/weed excluded)	114
Table 4.7	Frequent and abundant wild/weed taxa	115
Table 4.8	Distribution of the crop types and major wild taxa across the chronological phases	123
Table 5.1	Classification of samples based on the hulled wheat grain:chaff ratio	262-263
Table 5.2	Wild/weed taxa included in the crop processing analysis	264
Table 5.3a	Grain to rachis ratios of Amorgos barley calculated for the samples with minimum 30 barley remains	146
Table 5.3b	Grain to rachis ratios of Amorgos free-threshing wheat calculated for the samples with minimum 30 free-threshing wheat remains	147

Table 5.3c	Summary of grain to chaff ratios of the Amorgos free-threshing cereals	147
Table 5.4a	Barley grain:rachis ratios for Çatalhöyük samples containing minimum 30 barley remains	148
Table 5.4b	Free-threshing wheat grain:rachis ratios for Çatalhöyük samples containing minimum 30 free-threshing wheat remains	149
Table 5.4c	Free-threshing cereal (barley+free-threshing wheat) grain:rachis ratios for Çatalhöyük samples containing minimum 30 free-threshing cereal remains	150
Table 5.5	Classification of wild/weed taxa into crop processing physical types	152
Table 5.6	Classification of samples by the discriminant analysis using crop processing physical weed types; proportions of two major types (small-free-heavy and small-free-light) and other types also shown	265-266
Table 5.7	Combined results of crop-based and weed-based crop processing analysis also showing classification of samples based on their crop (hulled wheat) and *Descurainia* content	267-268
Table 5.8	Summary of results of the crop processing analysis	157
Table 5.9	List of samples containing dung pellets, fragmented dung and/or plant material embedded in dung	269
Table 5.10	Habitat preferences of the wild/weed taxa	270-271
Table 5.11	Classification of the wild/weed taxa based on their fruiting time in relation to the harvest time	272-273
Table 5.12	Classification of the samples entered as a 'fifth' (Çatalhöyük) group in the discriminant analysis, in addition to the four ethnographic (Amorgos) groups of samples	274
Table 5.13	Crop processing classification of the eight mixed crop samples	167
Table 5.14	Summary of habitat, seasonality and crop processing physical characteristics of the wild/weed taxa	275-276
Table 6.1	List of crop taxa included in the correspondence analysis	170
Table 6.2	List of wild taxa included in the correspondence analysis, and their different classifications	173-174
Table 6.3	List of samples for the correspondence analysis showing their archaeological context and classifications	179-180
Table 7.1	The origin of wild/weed taxa in the assemblage	189
Table 7.2	Selected ecological and biological characteristics of the dung-derived plant taxa	194
Table 7.3	Classification of arable taxa based on their lifecycle and habitat	211
Table 7.4	Flowering onset and duration information for the selected arable taxa as a basis for the estimation of crop sowing time	219
Table 7.5	Arable taxa for which FIBS data were available	223
Table 7.6	Results of the discriminant analysis showing the classification of samples as gardens or fields with high or low probability	301-302

Table 7.7 Classification of the selected weed taxa based on the maximum stem height 227
Table 7.8 Calculations of the required arable land for different population estimates at Çatalhöyük 236
Table 7.9 Calculations of the distances which Çatalhöyük residents would have travelled to their fields, in relation to the varying cereal yields and for different population levels 238
Table 7.10 The required arable land at Çatalhöyük for households of various sizes and for a range of cereal yields 239

Appendix I. Table 1 A preliminary list of weed taxa collected in einkorn and emmer fields in Kastamonu, Turkey 333
Appendix II. Table 1 Determining seed winnowability using seed velocities measured by the seed buoyancy machine 337

List of figures

Figure 1 Topographic map of Turkey showing Central Anatolian sites discussed in the text 4

[Map background licensed under the *Creative Commons Attribution-Share Alike 3.0 Unported* (CC BY-SA 3.0; http://creativecommons.org/licenses/by-sa/3.0/deed.en).
Map available at http://commons.wikimedia.org/wiki/File:Turkey_topo.jpg
Map inset - permission to use kindly granted by the author, Mr Burak Sansal, on 26 April 2013. All About Turkey© Burak Sansal 1996–2011. Available at http://www.allaboutturkey.com/regions.htm]

Figure 2.1 Areal view (from the northeast) of the Çatalhöyük mounds 15

[Photo© Orhan Dorgut. Available at http://www.panoramio.com/photo_explorer#view=photo&position=54& with_photo_id=16078702&order=date_desc&user=954967. Permission to include the photograph could not be obtained; the figure is removed from the dissemination copy of the thesis]

Figure 2.2 Topographic map of the Konya plain 16

[Map background licensed under the *Creative Commons Attribution-Share Alike 3.0 Unported* (CC BY-SA 3.0; http://creativecommons.org/licenses/by-sa/3.0/deed.en).
Map available at https://commons.wikimedia.org/wiki/File:Konya_plain_topographic_map-blank.svg
Map inset licensed under the *Creative Commons Attribution-Share Alike 3.0 Unported* (CC BY-SA 3.0; http://creativecommons.org/licenses/by-sa/3.0/deed.en).
Map available at https://commons.wikimedia.org/wiki/File:Konya_in_Turkey.svg]

Figure 2.3 Chronological sequence for Anatolia from *c.* 10,000 to 4500 cal. BC (Hodder 2005: Fig. 1.5) 17

[Permission to use the figure obtained from the publisher, the McDonald Institute for Archaeological Research, University of Cambridge, 13 May 2013]

Figure 2.4 Occupation levels at Çatalhöyük East (Hodder and Cessford 2004: Fig. 1) 18

[Permission to include the illustration could not be obtained from the copyright holder; the figure is removed from the dissemination copy of the thesis]

Figure 2.5 Excavation areas at Çatalhöyük East (Bogaard *et al.* 2009: Fig. 2a) 21

[First published in Bogaard, A., M.P. Charles, K.C. Twiss, A.S. Fairbairn, E.N. Yalman, D. Filipovic, G.A. Demirergi, F. Ertuğ, N. Russell and J. Henecke 2009 Private pantries and celebrated surplus: Saving and sharing food at Neolithic Çatalhöyük, central Anatolia. *Antiquity* 83: 649–668.
Permission obtained from http://antiquity.ac.uk/contact.html#permissions:
If you are the author of material published in Antiquity: Authors may reproduce their own work in printed form without requesting permission from Antiquity]

Figure 2.6 The mentioned locations in Central Anatolia with studied palaeoclimatic sequence 40

[Map background taken from Andrew Sherratt (2004), 'Sites from Satellites: Çatalhöyük, Turkey', ArchAtlas, Version 4.1, http://www.archatlas.org/SitesFromSatellites/sites.php?name=catalhoyuk)
Permission to use the map kindly provided by Dr Susan Sherrat, Sheffield University on 26/04/2013]

Figure 2.7a Summary pollen diagram from Eski Acigöl (ESK92 core) (Roberts *et al*. 2001: Fig. 6) 41
[Permission to include the figure granted by *The Holocene* journal (SAGE publications), 2 May 2013]

Figure 2.7b Correlation between the results from the palaeolimnological and palynological analysis (ESK92 core) at Eski Acigöl indicating environmental changes of the Late Pleistocene - Early Holocene transition (Roberts *et al*. 2001: Fig. 7) 42
[Permission to include the figure granted by *The Holocene* journal (SAGE publications), 2 May 2013]

Figure 2.8 Summary pollen diagram from Akgöl Adabağ (Woldring 2002: Fig. 2; reproduced in Roberts *et al*. 2007: Fig. 4.13) 43
[Permission to use Figure 2 from Woldring 2002 granted by the publishing company 'Ege Yayınları', Istanbul, Turkey (www.zerobooksonline.com) on 26 April 2013]

Figure 2.9 Soil types and landforms around Çatalhöyük (Fairbairn 2005: Fig. 1) 46
[Permission to use the illustration from *World Archaeology* journal (SAGE publications) provided through Rightslink® Copyright Clearance Center on 6 May 2013]

Figure 2.10 Reconstruction of the different Neolithic vegetation formations in the Konya plain based on the charcoal evidence from Çatalhöyük and Pınarbaşı A, the palaeoenvironmental analysis and data on the modern soil and vegetation distribution in the region (Asouti 2005: Fig. 10.19) 50
[Permission to use the figure obtained from the publisher, the McDonald Institute for Archaeological Research, University of Cambridge on 13 May 2013]

Figure 3.1 Diagram showing the relationship between the excavated structures in the South Area (Farid 2008: 20). **Inset**: the north-facing section of excavated zone in the South Area up to Level VI B/South N (Farid 2007: Fig. 3.5a) 255
[Illustration: permission to show the diagram kindly provided by the author, Ms Shahina Farid, on 30 April 2013. Inset: permission to use the figure obtained from the publisher, the McDonald Institute for Archaeological Research, University of Cambridge, on 13 May 2013].

Figure 4.1 Proportions of crop and wild material across the samples 94
Figure 4.2 Rachis segments of bread wheat (*Triticum aestivum* L.) 97
Figure 4.3a Basal rachis segment of six-row naked barley 98
Figure 4.3b Rachis segment of two-row naked barley 98
Figure 4.4a Fragments of the lentil pod 99
Figure 4.4b Fragments of the lentil stalk 99
Figure 4.5 Fragments of the pea pod 100
Figure 4.6a Relative proportions of the three crop groups and wild taxa across the samples 101
Figure 4.6b Relative proportions of the three crop groups 101
Figure 4.7a Relative proportions of crop plant parts across the samples 102
Figure 4.7b Relative proportions of crop plant parts in the assemblage 102
Figure 4.8a Relative proportions of grain/seed across the samples;

the lentil sample included 103
Figure 4.8b Relative proportions of grain/seed in the assemblage; the lentil sample included 103
Figure 4.9a Relative proportions of grain/seed across the samples after the removal of the lentil sample 104
Figure 4.9b Relative proportions of grain/seed in the assemblage after the removal of the lentil sample 104
Figure 4.10 Relative proportions of the crop groups across the samples 105
Figure 4.11a Representation of different plant parts within the hulled wheat group 105
Figure 4.11b Representation of different plant parts within the free-threshing cereal group 105
Figure 4.12 Classification of samples based on the crop content 107
Figure 4.13 Proportions of the general groups of wild taxa across the samples 110
Figure 4.14a Relative proportions of *Descurainia sophia*, other wild/weed taxa (including indeterminate wild/weed) and the fruit, nut and tuber group 120
Figure 4.14b Relative proportions of *D. sophia*, wild/weed taxa (including reed and indeterminate wild/weed), fruit, nut and tuber group, and crop content 121
Figure 5.1a Distribution of the 84 hulled wheat samples based on the proportions of hulled wheat grain, hulled wheat glume bases and potential weed taxa 143
Figure 5.1b Distribution of the hulled wheat samples coded by their grain:glume bases ratio classification (spikelet and glume bases samples) 143
Figure 5.1c Distribution of the ten *Descurainia*(/hulled wheat) samples 144
Figure 5.2 Scatter plot of the Çatalhöyük and Amorgos samples based on a discriminant analysis of the four crop processing groups 155
Figure 5.3 Scatter plot of the Çatalhöyük and Amorgos samples based on a discriminant analysis; Çatalhöyük samples entered as a separate group 165
Figure 6.1 Correspondence analysis plot of the 94 samples and 75 taxa showing relative proportions of crop and wild material 277
Figure 6.2 Correspondence analysis plot of the 94 samples and 75 taxa showing relative proportions of the three crop groups, wild taxa and *Descurainia* 277
Figure 6.3 Correspondence analysis plot of the 92 samples and 75 taxa showing relative proportions of the three crop groups, all wild taxa and *Descurainia* 278
Figure 6.4 Correspondence analysis plot of the 75 samples and 75 taxa showing relative proportions of the crop groups, all wild taxa and *Descurainia* 278
Figure 6.5 Correspondence analysis species plot showing distribution of some major crop types and wild taxa 279
Figure 6.6 Correspondence analysis plot showing the 28 dung-containing samples 279
Figure 6.7 Correspondence analysis plot showing relative proportions of the taxa observed in dung 280
Figure 6.8 Correspondence analysis species plot showing distribution of the taxa observed in dung 280

Figure 6.9a-k Correspondence analysis attribute plots showing the contribution of the selected wild/weed taxa 281-283
Figure 6.10 Correspondence analysis species plot showing distribution of the taxa observed in dung and the taxa co-occurring with these 283
Figure 6.11 Correspondence analysis plot showing relative proportions of crop processing physical types of the wild/weed taxa 284
Figure 6.12 Correspondence species analysis plot showing distribution of crop processing physical types of the wild/weed taxa 284
Figure 6.13 Correspondence analysis plot showing relative proportions of different seasonality (fruiting time) categories of the wild/weed taxa 284
Figure 6.14 Correspondence analysis species plot showing distribution of different seasonality (fruiting time) categories of the wild/weed taxa 285
Figure 6.15 Correspondence analysis plot showing relative proportions of different habitat categories of the wild/weed taxa 285
Figure 6.16 Correspondence species analysis plot showing distribution of different habitat categories of the wild/weed taxa 285
Figure 6.17 Correspondence analysis plot showing archaeological context types for the 75 samples 286
Figure 6.18 Correspondence analysis plot showing depositional character of the 75 samples 286
Figure 6.19 Correspondence analysis plot showing internal/external derivation ('location') of the 75 samples 287
Figure 6.20 Correspondence analysis plot showing depositional character and location of the 75 samples 287
Figure 6.21 Correspondence analysis plot showing the excavation areas for the 75 samples 287
Figure 6.22 Correspondence analysis plot showing Building (B.) and Space (Sp.) derivation for the 75 samples 288
Figure 6.23 Correspondence analysis plot showing the chronological phases for the 75 samples 288
Figure 6.24 Correspondence analysis plot showing distribution of the wild-rich and hulled wheat samples after the removal of crop categories (i.e. the 'wild-only' analysis) 289
Figure 6.25 Correspondence analysis species plot showing distribution of the dung-derived and other wild/weed taxa 289
Figure 6.26 Correspondence analysis plot showing relative proportions of the dung-derived taxa, *Descurainia* and other wild/weed taxa 290
Figure 6.27 Correspondence analysis species plot showing distribution of the dung-derived taxa, *Descurainia* and other wild/weed taxa 290
Figure 6.28 Correspondence analysis plot showing relative proportions of crop processing physical types of the wild/weed taxa 291
Figure 6.29 Correspondence analysis plot showing distribution of crop processing physical types of the wild/weed taxa 291

Figure 6.30 Correspondence analysis plot showing classification of the 75 samples in the crop processing analysis 291
Figure 6.31 Correspondence analysis plot showing relative proportions of the seasonality (fruiting time) categories of the wild/weed taxa 292
Figure 6.32 Correspondence analysis plot showing distribution of the seasonality (fruiting time) categories of the wild/weed taxa 292
Figure 6.33 Correspondence analysis plot showing relative proportions of the habitat categories of the wild/weed taxa 292
Figure 6.34 Correspondence analysis plot showing distribution of the habitat categories of the wild/weed taxa 293
Figure 6.35 Correspondence analysis plot showing archaeological context types 293
Figure 6.36 Correspondence analysis plot showing the depositional character (primary/secondary) of the samples 294
Figure 6.37 Correspondence analysis plot showing internal/external derivation of the samples ('location') 294
Figure 6.38 Correspondence analysis plot showing the depositional character and location of the samples 295
Figure 6.39 Correspondence analysis plot showing Building (B.) and Space (Sp.) derivation of the samples 295
Figure 6.40 Correspondence analysis plot showing the excavation areas 296
Figure 6.41 Correspondence analysis plot showing the chronological phases 296
Figure 6.42 Correspondence analysis plot showing distribution of the wild-rich and hulled wheat samples after the removal of crop categories and *Descurainia* (as well as three samples with <30 items) 297
Figure 6.43 Correspondence analysis species plot showing distribution of the dung-derived and non-dung taxa 297
Figure 6.44 Correspondence analysis plot showing relative proportions of the habitat categories of the wild/weed taxa 298
Figure 6.45 Correspondence analysis species plot showing distribution of the the habitat categories of the wild/weed taxa 298
Figure 6.46 Correspondence analysis plot showing archaeological context types 298
Figure 6.47 Correspondence analysis plot showing the depositional character and location of the samples 299
Figure 6.48 Correspondence analysis plot showing Building (B.) and Space (Sp.) derivation of the samples 299
Figure 6.49 Correspondence analysis plot showing the excavation areas 300
Figure 6.50 Correspondence analysis plot showing the chronological phases 300
Figure 7.1 Correspondence analysis combined plot showing distribution of C3 and C4 taxa and the samples deriving from different excavation areas (75 samples and 52 wild taxa included, see Section 6.2) 201
Figure 7.2 Correspondence analysis plot showing relative proportions of C3 and C4 taxa (75 samples and 52 wild taxa included, see Section 6.2) 201

Figure 7.3a Relative proportions of the arable taxa based on their lifecycle and habitat 212
Figure 7.3b Overall ubiquity of the groups of arable taxa 212
Figure 7.4a The distribution of Evvia pulse gardens and fields in relation to the discriminant function extracted to distinguish between Evvia gardens and fields 222
Figure 7.4b The relationship of Çatalhöyük samples to the discriminant function used to discriminate between Evvia fields and gardens 222
Figure 7.4c The relationship of Çatalhöyük samples to the discriminant function used to discriminate between Evvia fields and gardens plotted with Evvia group centroids 222
Figure 7.5a Relative proportions of the arable weed taxa classified according to their stem height 228
Figure 7.5b Overall ubiquity of the arable weed taxa classified according to their stem height 228
Figure 7.6 The arable land requirement for households of different sizes 239

Chapter 1 Introduction

The present study is focused on the production and interpretation of new evidence for plant and land use in the early-mid Neolithic sequence (*c*. 7400-6600 cal. BC - Cessford *et al*. 2005) of Çatalhöyük in Central Anatolia, Turkey. The large archaeobotanical dataset recovered through systematic sampling of the excavated deposits offers great potential for investigating key questions about plant use at the site and, in particular, the nature of crop and animal husbandry. Farming and herding were fundamental components of the economy of established Neolithic communities in south-west Asia and played a central role in the construction of daily life. Through the study of archaeobotanical remains, much can be inferred about agricultural practices and plant-related tasks and activities, the ways in which early farmers shaped the landscape, as well as the socio-economic implications of early agricultural lifestyles. In particular, discussion of the social organisation of Neolithic communities has been the focus of much previous and recent research (see below), and the role of agriculture in the formation of these communities has been widely discussed. This study focuses on key aspects of food production that constrained and shaped social life at Çatalhöyük.

1.1 Agricultural expansion and social change in Neolithic south-west Asia

For vast areas of south-west Asia, the culmination of Neolithic developments is associated with the Pre-Pottery Neolithic B phase (PPNB) defined at Jericho and subsequently used as a broad chronological reference for other areas in the region (e.g. Simmons 2000; Byrd 2005a). This is the period of agricultural expansion and the time when definitive plant and animal domestication emerged, following millennia of intensive (wild) plant and animal exploitation by sedentarising hunter-gatherer communities (e.g. Harris 2002; Kuijt and Goring-Morris 2002; Nesbitt 2002; Simmons 2007; Willcox *et al*. 2008; Zeder 2005, 2011; Colledge 2001; Bar-Yosef and Belfer-Cohen 1989; Cauvin 2000; Colledge and Conolly 2007; Fuller *et al*. 2012). In Central Anatolia this period marked the earliest plant and animal husbandry of the region, manifested by the presence of (at least some) domesticated forms in the archaeological record, of which the earliest were found at the site of Aşıklı Höyük (Helbaek 1964; van Zeist and de Roller 1991-1992, 1995; Buitenhuis 1997; Martin *et al*. 2002;

Fairbairn *et al*. 2005a; Russell and Martin 2005; Arbuckle *et al*. 2009). The shift in subsistence practices from foraging to food production was accompanied by the establishment of large villages with substantial architecture, population growth, aggregation and sedentism, as well as technological advances such as new lithic forms, followed by the introduction of pottery in later Neolithic phases (e.g. Flannery 1972; Banning 2003; Byrd 2004; Last 2005a; Maher *et al*. 2012). These innovations in economic and material spheres are viewed as closely associated with the transition from communal to household (food) production (e.g. Flannery 1972, 2002; Wilk and Netting 1984; Netting 1990), whereby the residential household arose as the fundamental social, economic, and ritual unit of the Neolithic society in south-west Asia (Kuijt 2000; Hodder 2007). The emergence of the household as the basic social unit is linked with increasing complexity in social organisation as a result of potential differences in the household-based production levels, social differentiation and mechanisms for negotiating the differences (e.g. Flannery 1972, 1995, 2002; Moore 1985; Bar-Yosef and Meadow 1995; Kuijt 2000; Byrd 2005b; Asouti 2006).

An important aspect of the Neolithic developments is the nature of adjustments of hunter-gatherer social practices to accommodate the routines of agricultural production around which daily life was structured, in addition to changing patterns of social interaction derived from increased dependence upon plant and animal management and the required labour input. The adjustments are particularly visible in architectural changes - the emergence of new settlements of variable extent, from relatively small and comparable in size to those of the late Epipalaeolithic semi-sedentary hunter-gatherers, to occasional 'megasites' of more than 10 ha, located in areas reasonably favourable to farming, and including structures (houses) with standardised floor-plans and internal food storage and preparation features (Byrd 1994, 2005a; Banning 1998, 2003; Bar-Yosef and Meadow 1995; Wright 2000; Kuijt 2000; Simmons 2007). These 'village' communities likely represented integrated families with shared beliefs and established rights to economic resources (Flannery 1995); various socio-political mechanisms, such as highly structured food production and consumption (Byrd 1994, 2005a, 2005b), were probably developed in order to ensure survival, maintenance and reproduction of the community, perhaps contributing to the exceptional continuity of some of them (e.g. Mellaart 1967; Rollefson 1987; Rollefson *et al*. 1992; Moore *et al*. 2000; Asouti 2006).

Early PPNB sites in the Levant reflect a series of transformations in the arrangement of living space in comparison with earlier PPNA settlements; they consisted of relatively large (compared to PPNA) agglomerations of rectangular buildings, with interiors divided into (functional) segments (using posts, raised surfaces, niches) which, in combination with other archaeological evidence, suggests differentiation between private and public spheres of activity; it is assumed that the houses still accommodated small nuclear families, as was the case in previous periods (Byrd 2005a, 2005b; Banning 2003). The organisation of residential structures is understood as pertinent to changes in the relationship between domestic/private and public (communal) areas and activities, whereby the household became the basic socioeconomic unit, to some extent independent from community-level affairs (Byrd 1994, 2005a). As well as changes in the settlement layout and spatial organisation of the community, a shift from communal (food) sharing within the hunter-gatherer groups to private, family-based storage and consumption in sedentary communities has been recognised based on the decline of communal granaries and frequent occurrence of household storage (Flannery 1972; Banning 1998, 2003; Byrd 2005a; Peltenburg 2004). Furthermore, features and artefacts related to food preparation become less visible and accessible to members of the broader community, and are associated with individual houses (Wright 2000).

An insight into social interactions in early farming communities could be obtained from elements of the built environment - for example the occurrence of non-domestic public structures such as those in the Levant, at Beidha (Byrd 2005a, 1994) and 'Ain Ghazal (Rollefson *et al*. 1992), and at some Anatolian sites including Aşıklı Höyük in Cappadocia ('T' and 'HV' buildings - Esin and Harmankaya 1999; Esin *et al*. 1991) and Çayönü and Nevali Çori in south-eastern Anatolia (Özdogan and Özdogan 1989; Schirmer 1990; Hauptmann 1993). These 'special' buildings are significantly larger than assumed residential units and are often distinct in terms of architecture and associated artefacts (e.g. red-painted walls and floors, paved floors; internal stone slab monoliths, benches and stone tables); they have been interpreted as possible 'shrines' intended for ceremonial and ritual activities (e.g. feasting - Hayden 2001) that perhaps involved, and were relevant to, the whole community (Byrd 1994, 2005a). Furthermore, construction of non-domestic buildings would have required labour investment from the wider community, which would result in interactions beyond those occurring within a household (Byrd 1994, 2005a) or a neighbourhood (Düring 2006). This could be understood as the evidence of political mechanisms for encouraging group integration and cohesion of the village population (Byrd 2005a: 134).

1.1.1 **The case of Çatalhöyük, Central Anatolia**

Çatalhöyük East represents one of a number of extraordinary large early farming settlements ('megasites') that emerged in south-west Asia during the later Pre-Pottery Neolithic and into the Pottery Neolithic, but is one of few that survived a major regional population shift in the mid-7th millennium BC in Central Anatolia (Baird 2002, 2005) and the 'collapse' of PPNB (Rollefson and Kohler-Rollefson 1989; Kuijt 2000). Instead, it flourished for over a millennium (*c*. 7400-6200/6000 cal. BC) through the Pottery Neolithic (PN), displaying exceptional stability that continued further into Chacolithic, when the settlement shifted from the East to the West Mound (6000-5500 cal. BC - Cessford 2001).

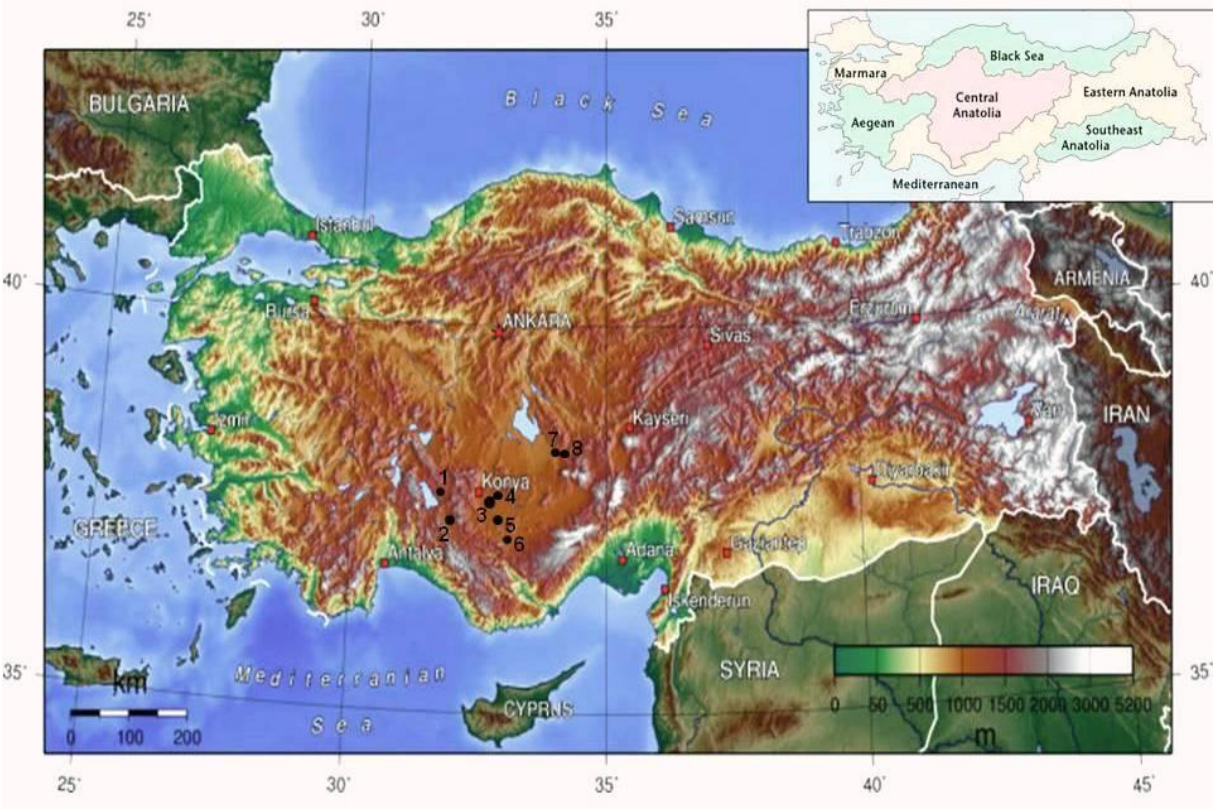


Figure 1 Topographic map of Turkey showing Central Anatolian sites discussed in the text: 1) Erbaba, 2) Suberde, 3) Çatalhöyük, 4) Boncuklu, 5) Pınarbaşı A, 6) Canhasan III, 7) Aşıklı Höyük and 8) Musular.

(Map background - http://en.wikipedia.org/wiki/File:Turkey_topo.jpg#filelinks; Inset - http://www.allaboutturkey.com/regions.htm)

In the region of Central Anatolia (Fig. 1), extending from the Konya-Ereğli plain in the west to Cappadocia in the east, the earliest permanent sedentary occupation is documented at Aşıklı Höyük in Cappadocia at around 8500 cal. BC, lasting until *c*. 7500 cal. BC (Esin *et al*.

1991; Esin and Harmankaya 1999); it belongs to the aceramic Neolithic and directly predates Çatalhöyük East. The two sites are similar in that, among other aspects, both Aşıklı and the early-mid levels at Çatalhöyük reveal closely spaced (agglutinated) buildings organised in neighbourhood blocks separated by streets, alleyways and/or middens, and composed of clusters of about 30 (Çatalhöyük Pre-Level XII-Level VI/South G-N) or 30-40 buildings (Aşıklı Höyük) accessed from the flat roofs (Mellaart 1967; Esin *et al*. 1991; Hodder 1996; Özbaşaran 2000; Düring 2005, 2006; Düring and Marciniak 2006). Based on this, and certain other characteristics of the neighbourhoods (see Düring and Marciniak 2006), it has been argued that, in the early phase of Early Central Anatolian (ECA II), to which Aşıklı Höyük and early-mid Çatalhöyük sequence belong (see below, Section 2.1.2), the neighbourhood rather than household was the key social entity, though at Çatalhöyük the household assumed a more prominent role (Düring and Marciniak 2006; Düring 2007). It has further been suggested that some buildings within neighbourhoods had a 'special' status based on their longevity, elaboration and numbers of subfloor burials (Hodder 2005, 2006; Düring and Marciniak 2006).

The emergence of the household as the major food production-consumption unit in the PPNB is primarily inferred from the architectural evidence, which is understood as indicating the development of household autonomy (Flannery 1972, 2002; Byrd 1994, 2005a, 2005b; Banning 1998, 2003; Kuijt 2000). However, other forms of evidence, i.e. subsistence-related, are required in order to actually demonstrate the change in the cultural control of the food economy (e.g. Bogaard *et al*. 2009, in press/2013; also Twiss 2007; Twiss *et al*. 2009). This is particularly critical in circumstances of social crowding within PPNB settlements (Kuijt 2000), where cultivation and herding, as forms of resource intensification entailing significant labour input to improve productivity (Byrd 2005b), led to increasing formalisation of land ownership rights and access to resources (Byrd 2005a) and, perhaps as a consequence, secluded food storage, preparation and consumption (Wright 2000; Bogaard *et al*. 2009). The new land-use and food production strategy altered the organisational structure of the community by shifting the focus from the communal group to family-based/household units (Byrd 2005b) on the basis that labour investments in farming are best managed by families (willing to share with kin and having full control of workforce), who in turn develop rules and take control over food production, storage and consumption (Flannery 1972; Byrd 1994, 2005b).

In Central Anatolia, it appears that the rise of the household as a central social unit, triggered by changes in the economy, was a 'postponed' slow/gradual process, and that the household functioned within larger entities - neighbourhoods, encompassed by the settlement as a whole, long after the adoption of the 'domestic mode of production' (Düring 2006). The neighbourhood system suggested for Çatalhöyük could perhaps be viewed as a strategy towards social equality and promotion of solidarity in the likely circumstances of differences in household production. Still, it appears that household autonomy was valued at least to some extent since, for example, even though houses were closely packed together, they rarely shared walls (Hodder and Cessford 2004; Cutting 2005); furthermore, each house/household had its own food-related facilities (storage area, cooking equipment etc - Hodder and Cessford 2004; Bogaard *et al*. 2009).

1.1.2 **The nature of agriculture in Neolithic south-west Asia**

Recent research into the emergence of agriculture and animal herding shows that these developments occurred at roughly the same time in the northern Fertile Crescent, and as a result of protracted management of the wild ancestors lasting more than a thousand years and occurring over multiple geographic regions including the north and south Levant, as well as the 'core area' of south-east Turkey; hence the level of subsequent adoption/use of domesticated crops and animals was uneven and varied across south-west Asia (Willcox 2002a; Peters *et al*. 2005; Zeder 2008, 2011; Fuller *et al*. 2011; Maher *et al*. 2012). The simultaneous or, rather, potentially *combined* occurrence of plant and livestock (especially sheep/goat) domestication is crucial to the understanding of the nature of early agriculture in south-west Asia as well as its social, economic and ecological significance for the development, continuity and (in)stability of the settlements (e.g. Rollefson 1997; Simmons 2000; Bogaard 2005; Bogaard and Isaakidou 2010). Whereas mobile and semi-sedentary hunter-gathering economies are inherently extensive, with foragers exploiting natural resources dispersed over wide areas, sedentary economies are focused on intensive exploitation of local, often limited, resources, their sufficiency exacerbated by growing settlement population (Byrd 2000). The system of food production therefore had to be aimed at maximising the available resources by high labour investment per unit area or animal, in order to offer a robust subsistence basis for the community.

Securing subsistence would, therefore, have represented a significant challenge for sedentary traditions (e.g. Bar-Yosef and Belfer-Cohen 1991; Zeder 2011) and likely required adjustments of previous (hunter-gatherer) food procurement/production techniques. Some aspects of cultivation and herding could have been combined as early as the PPNA (Zeder 2011), as part of major economic changes of the time, while a close integration of the two could have fully developed in the PPNB and would have been a highly practicable subsistence strategy. For example, cultivation plots can supply forage and fodder for livestock, while herding can provide manure which improves/maintains soil fertility and tractability (ease of soil working) and regulates crop growth (i.e. prevention of lodging by promoting of tillering in cereals - Ellenberg 1988; Bogaard 2004a, 2005; Halstead 2006; Bogaard and Isaakidou 2010). The production potential of cultivated areas could have been further improved by practices such as dibbling or row sowing (which make more efficient use of the seed corn than sowing by broadcasting), tilling and manual weeding/hoeing and watering/drainage - all of which added to the creation of 'artificial' crop growing conditions, transferable across different geographical zones (Halstead 1987, 1989, 1995, 2006; Jones *et al*. 1999; Bogaard 2004a, 2004b, 2005; Jones 2005). The truly intensive nature of farming implies cultivation of restricted areas ('gardens') and tending of small flocks of animals in close proximity to the farming household/settlement (Halstead 1989; Jones *et al*. 1999; Jones 2005; van der Veen 2005), so as to enable the application of high labour inputs and transfer of manure from stalls to the fields, or keeping of animals in fenced fields for a limited time; as the distance of fields becomes greater, the intensity of cultivation decreases, while animals become prone to attacks from predators (Jones *et al*. 1999).

It has been suggested that the ideal settlement pattern for intensive farming is the one with dispersed farmsteads surrounded by cultivation plots (Bogaard and Isaakidou 2010). Across Central Anatolia, the majority of more or less contemporary Neolithic sites are characterised by closely spaced buildings, repeatedly built on top of earlier ones, forming mounds similar to those found at Çatalhöyük. The first impression could be that the agglomerated households are at a disadvantage in terms of the proximity to cultivation plots and the potential for intensive agriculture. However, as will be shown below, under intensive cultivation regime the arable land located within a relatively short distance (<5 km) from the settlement at Çatalhöyük could have provided reasonably high yields, sufficient to support the growing population even at its peak. In fact, the potential for agricultural production and the predictability of yields may, at least partly, have been a reason behind "the enduring

concentration of population" at Çatalhöyük (Baird 2002: 149). The close proximity of Çatalhöyük houses/households could have been aimed at enhancing the sense of community and belonging (Asouti 2005a, 2006), while it would have also facilitated sharing (of food and other products/objects, as well as experience, knowledge, news) which perhaps was the fundamental social strategy for overcoming tensions and negotiating conflicts (Bogaard *et al*. 2009).

1.2 The present study

The present study investigates plant and land use practices through the early-mid occupation sequence at Neolithic Çatalhöyük. The overarching question is: what economic strategies enabled the Çatalhöyük East community to develop into an early farming 'town' and maintain its size and complexity over centuries? In particular, the work aims to shed light on the relationship between crop growing and animal herding, since the full integration (moreover, interdependence) of crop and livestock management may have been the foundation stone for survival of the settlement through its early and 'mature' phase, and into the later period (i.e. the late Neolithic - beginning of the PPNC at around mid-7th millennium), when some other sites in Central Anatolia were abandoned (e.g. Canhasan III, Süberde), while new ones were founded (Erbaba III, Pınarbaşı B) (Baird 2002). The study seeks to refine previous interpretations and suggested models of crop husbandry at Çatalhöyük and to improve current understanding of the role of agriculture as a subsistence and social strategy at the site.

Renewed excavations at Çatalhöyük have used a range of state-of-the-art recovery techniques, including systematic sampling of archaeological deposits for archaeobotanical remains. Thousands of archaeobotanical samples have been recovered at Çatalhöyük, offering the first and unique opportunity to directly investigate the socio-economic organisation of the community from the agricultural perspective. Only a very small proportion of the large 'archive' of samples from the early-mid Neolithic levels has previously been studied in detail (Helbaek 1964; Asouti and Fairbairn 2002; Fairbarn *et al*. 2002, 2005a; Cane *et al*. 2012). The results of the analysis revealed that a diverse range of cereals and pulses were used, suggesting the important economic role of crop cultivation, supplemented by wild plant gathering; they confirmed the widespread presence of animal dung across the deposits, noted

also in micromorphological analysis, and suggested that crop material was fed to livestock, indicating a close relationship between crop and animal husbandry (Fairbairn *et al*. 2002, 2005a; Matthews 2005a, 2010). Previous studies also drew attention to the potentially complex taphomony of the botanical assemblage (see below), featuring a mixture of material derived from various sources, especially crop processing and burning of animal dung as fuel (Fairbairn *et al*. 2005a); as a result, many questions related to the nature of agriculture, the relationship between crop and animal husbandry, and specifically the nature of arable and pastoral management at Çatalhöyük remain to be addressed.

Therefore, one of the principal objectives of this study is to disentangle the effects on the archaeobotanical assemblage of two major taphonomic processes: a) the use of animal dung as fuel, and b) processing of crops, and to identify the plant material deriving from these two different sources. Specific questions most in need of being answered here are:

- How did crop processing and consumption practices affect the assemblage?
- How did the use of animal dung as fuel contribute to the botanical assemblage?

Once the taphonomic issue is resolved, the study turns to the second key objective: investigation of the nature of land use practices, including crop husbandry, with particular reference to a) farming intensity, scale and location, and b) aspects of animal diet such as the variety, seasonality and availability of graze/fodder. Questions addressed include the following:

- What was the scale and intensity of arable production at Çatalhöyük?
- What was the nature of crop husbandry - was it local or distant? Where were the fields located? What were the crop growing conditions?
- What were animals fed? Where were they kept? Was crop management segregated from livestock keeping or integrated with it?

A final objective is to re-assess the relationship between crop and animal husbandry, and the social, economic and ecological significance of crop cultivation for the development and longevity of the settlement.

1.2.1 **The issue of assemblage formation at Çatalhöyük**

Identifying the sources of plant material in archaeological deposits, and their means of introduction into the archaeological record, is necessary for the reconstruction of plant exploitation in the past. Plants represented in an archaeobotanical assemblage may originate

from different parts of the landscape, including both natural and anthropogenic habitats (e.g. Hillman 1981, 1984a; Green 1982; Jacomet and Kreuz 1999: 69-94), and their remains may result from a number of different processes related to the use of plants (e.g. Ertuğ-Yaraş 1997; Ertuğ 2000; Atalay and Hastorf 2006).

Previous archaeobotanical studies at Çatalhöyük have shown that plant material is mostly preserved by charring, although silicified/calcified remains were also found, and occasional mineralized seeds were present in some contexts (Fairbairn *et al*. 2005a; Hastorf 2005). The predominance of charred plant remains suggests that plant materials derived from the burning of fuel, including potentially animal dung (e.g. Miller and Smart 1984; Miller 1996; Charles 1998), as well as by-products of crop processing (the remains of crops and their weeds) (e.g. Green 1982; Jones 1987) may be prominent in many samples.

Earlier archaeobotanical work at the site has shown that the remains of crops (cereals and pulses) are the most ubiquitous in all excavation levels (Helbaek 1964; Mellaart 1967; Todd 1976; Fairbairn *et al*. 2002, 2005a); of the crops attested at Çatalhöyük, cereals have been identified as the main staple food, with remains of hulled wheats (mainly emmer) dominating the assemblage. Much of the evidence for cereal cultivation at Çatalhöyük comes from the charred remains of chaff, which is considered to have derived from cereal processing and is understood as the main indicator of the scale of cereal production and consumption (Fairbairn *et al*. 2005a). Another major contributor of plant material is animal dung, widely used as fuel (and perhaps other purposes) throughout the site's occupation; this practice therefore has major implications for identifying the source of plant remains in different archaeological contexts.

As part of the present study, and one of its main foci, detailed taphonomic analysis of the samples was carried out in order to determine the origin of crop material in various archaeological contexts. The use of chaff as animal fodder, tinder, bedding and as temper in pottery and mudbrick has been suggested (Fairbairn *et al*. 2005a; Atalay and Hastorf 2005, 2006; Matthews 2005a; Tung 2005); the practice of adding chaff to animal dung made into cakes burnt as fuel must also be considered (e.g. Ertuğ 1997; Anderson and Ertuğ-Yaraş 1998). The same ambiguities surrounding the 'mode of arrival' of cereal chaff and other crop remains also pertain to the wild plant content of the archaeobotanical record. Wild seeds can

enter archaeological deposits in a number of ways (e.g. Green 1982) and it is necessary to isolate different sources as far as possible before attempting further interpretation.

It is particularly important to distinguish between wild/weed material from arable and other pastoral habitats, in order to identify grazing/foddering practices on the one hand, and crop husbandry practices on the basis of arable weeds associated with the crops on the other. The ecology of arable weed species can provide essential information on agricultural practices such as sowing times, measures taken to improve crop growing conditions, intensity of cultivation and so on (e.g. Hillman 1981; van der Veen 1992; Charles *et al*. 1997; Jones 2002; Bogaard 2004a). Dung-derived wild plant material can offer insight into animal diet and perhaps also, based on the ethnoarchaeological and experimental studies, shed some light on dung-fuel preparation practices (e.g. Miller 1984; Miller and Smart 1984; Charles 1988; Charles and Bogaard 2005, 2010).

The contribution of dung-derived plant material to charred crop and 'weed' assemblages potentially conflates evidence of crop husbandry with that of animal diet at Çatalhöyük. Therefore, as has already been noted (Fairbairn *et al*. 2005a; Fairbairn 2005), much more detailed insight into sources of plant remains in different contexts is required in order to infer growing conditions, cultivation regimes, grazing areas and so on.

1.2.2 **Arable and pastoral land use at Çatalhöyük**

Another issue relevant to the research into the nature and scale of agriculture and its social significance at Çatalhöyük is the availability and extent of land suitable for crop cultivation around the settlement. Based on the results of the geomorphological survey by the KOPAL team, an environmental model was proposed for the site by Roberts *et al*. (1996, 1999; Rosen and Roberts 2005; Boyer *et al*. 2006; Roberts and Rosen 2009). It was suggested that the closest areas of dry land to the Neolithic settlement would have been sand ridges about 7 km to the south, but that their limited extent and low-nutrient status would not have provided reliable crop-yields (Roberts and Rosen 2009); furthermore, they may not have been sufficient to support the needs of the growing number of inhabitants (Cessford 2005). It is therefore argued that the most likely location for 'dry farming' would be low hills more than 13 km away (Roberts *et al*. 1999; Fairbairn *et al*. 2002; Rosen and Roberts 2005; Roberts and Rosen 2009). In both cases, the distance of cultivable land would have been far beyond the

suggested distance Neolithic farmers would regularly travel to their fields (Higgs and Vita-Finzi 1972). This implies that the risk of lower yields would be higher, that the crop fields would be more prone to damage by animals, and that a certain number of the inhabitants would need to spend some time away from the settlement for seasonal activities such as planting, harvesting etc (Rosen and Roberts 2005). It is argued, therefore, that crop husbandry was of minor economic importance for the Çatalhöyük inhabitants compared with hunting and wild plant gathering. Thus, in contrast to the available archaeobotanical evidence, the central position of agriculture in the Çatalhöyük subsistence economy has been questioned and a greater role has been suggested for other strategies, such as hunting and wild plant exploitation (Rosen and Roberts 2005; Atalay and Hastorf 2005, 2006; cf. Özdoğan 1997a, 1997b). Different sets of evidence have been drawn into this 'minimalist' view of agriculture at the site, including for example the focus on predominantly wild animals in the art (e.g. Hodder 2003, 2006).

However, reconsideration of the possibility of *local* cultivation based on the arable potential of modern soils and their distribution in the area around Çatalhöyük (Baird 2005; Fairbairn 2005; Donovan 2005) and, more importantly, new geomorphological work at the site (Doherty *et al*. 2007, 2008) suggest that the extent of high dry ground suitable for cropping was likely underestimated in the previous accounts, and that the Neolithic landscape could have been more favourable for farming than proposed by the current model. This also brings into question the proposed limited importance of crop cultivation (e.g. Hodder 1999; Rosen and Roberts 2005; Roberts and Rosen 2009).

The present study examines the aspects of crop cultivation that relate to its nature - extensive or intensive, large- or small-scale, local or distant - and explores the idea that crops and to some extent livestock were tended in artificially created and maintained habitats that were the product of high labour inputs of many generations over a number of years, and, to a certain extent, buffered from the natural environment.

1.3 Thesis structure

Chapter 2 outlines the location, chronology and archaeology of Çatalhöyük East and summarises the results of previous work on macrobotanical remains related to plant use and

environment reconstruction relevant for this study. It also presents information on the present-day climate and vegetation of the region and provides an overview of the proposed palaeoenvironmental models for Neolithic Çatalhöyük. In Chapter 3, field and laboratory methods used for sample recovery, selection and analysis are described, as well as techniques and approaches taken in statistical and ecological analysis of the data. Chapter 4 provides an overview of the results of the archaeobotanical analysis, and offers an insight into general sample composition, frequency and abundance of the taxa. Chapter 5 discusses formation processes (taphonomy) relevant to the Çatalhöyük assemblage; here, ethnoarchaeological models and multivariate statistical techniques are applied in order to identify and disentangle various sources of plant remains in archaeological contexts, and processes affecting their deposition and preservation. In Chapter 6, exploratory multivariate statistical analysis (i.e. correspondence analysis) is carried out with the aim of identifying and interpreting major trends in the archaeobotanical data using archaeological and plant ecological variables. On the basis of the results presented in Chapter 6, in Chapter 7 taxa relevant to the crop growing environment are identified and interpreted in order to infer individual aspects of crop growing during the early-mid Neolithic occupation at Çatalhöyük East – the permanence and location of fields, sowing time, harvesting method. Furthermore, aspects of animal diet based on the ecology of dung-derived taxa are considered. The final chapter (Chapter 8) provides an overview of the results with respect to the research questions, and considers socio-economic implications of plant use and husbandry at Çatalhöyük.

Chapter 2 Archaeological and environmental background

The following sections provide a strategic overview of the site's natural and culture-historical setting, a summary of previous archaeobotanical work at the site and in the region, and environmental data relevant to the study.

2.1 Archaeology

From the very beginning of excavations at Çatalhöyük in the 1960's, the site was perceived as a major Neolithic settlement in the region, a centre of urbanism and a predecessor of later elaborate civilisations, a culmination of Neolithic art, crafts and technology, economy, trade, ritual and symbolism (e.g. Mellaart 1967; Todd 1976). Discoveries since the 1960's have revealed many other earlier, contemporary and later sites in Central Anatolia and beyond, that comprise similarly large settlements with rich and complex material culture (e.g. Mellaart 1975; Özdoğan 1999; Özdoğan *et al*. 2003). These discoveries in many ways helped to contextualise and explain Neolithic developments at Çatalhöyük and in Anatolia more generally and, while Çatalhöyük remains prominent in terms of its symbolic complexity (Hodder 1999, 2007), it is now more often discussed as part of a wider cultural phenomenon.

2.1.1 Location

The site of Çatalhöyük consists of a pair of mounds/tells – the Neolithic East Mound, and the Chalcolithic West Mound (Fig. 2.1) - located near the modern town of Çumra in the central part of the Konya plain, on the southern edge of the Central Anatolian Plateau in south-central Turkey (Fig. 2.2) (Mellaart 1967; Hodder 1996). The Konya basin lies at an elevation of *c*. 1000 m above sea level and is surrounded to the north and east by the Anatolides chain, and to the south by the Taurus mountain range, with a volcanic massif of Karadağ (*c*. 2000 m asl) in the centre of the basin; the site itself lies at an altitude of *c*. 980 m (de Ridder 1965: 231; Driessen and de Meester 1969: 7-8; de Meester 1970: 20; Roberts *et al*. 1996). The mounds are situated on an inactive alluvial fan, on opposite sides of an old branch of the river Çarsamba Çay that runs from the Taurus Mountains (in the south) northwards into the Konya plain. In addition to the Çarsamba river a number of other watercourses enter the plain from

the Taurus Mountains and form a range of features in the landscape - alluvial fans, marshes and lakes (de Ridder 1965: 233; de Meester 1970: 22; Roberts *et al*. 1996).



Figure 2.1 Areal view (from the north-east) of the Çatalhöyük mounds

(Photo credit ©Organ Durgut; available at http://www.panoramio.com/photo_explorer#view = photo&position=54& with_photo_id=16078702&order=date_desc&user=954967, retrieved 16/09/2012)

According to recent geomorphological work at the site, alluviation in the Çarşamba river catchment began before the initial occupation of Çatalhöyük and continued throughout its history, laying down 'backswamp clay' (black organic fine-grained clayey sediment) on top of water-retentive lake marl that impeded the drainage of surface water. The lake marl likely represented a gently undulating surface, but was probably flattened and any depressions filled up soon after the start of alluviation (Roberts *et al*. 1996, 1999; Boyer *et al*. 2006). Assuming that the landscape was generally flat at the time of Çatalhöyük, as it mostly is today, the existing landscape model suggests that the area around the site and the whole basin of Konya would have been wet for much of the year from the inflow of the Çarşamba river and spring floods from snowmelt on the surrounding mountains (Roberts *et al*. 1996, 1999; Rosen and Roberts 2005). With nearly no drainage of water through clayey alluvial deposits and lake marl ('except for some karstic sink-holes' and 'evaporation in summer or internal drainage' - Rosen and Roberts 2005; Boyer *et al*. 2006: 679), ground- and surface-water levels would

have been high and the settlement would have been an 'island' surrounded by marshes and wetlands. This 'challenging' location of Çatalhöyük from the economic and logistic point of view has raised a question central to many Çatalhöyük-related studies - 'why was it there?' (Hodder 2005: 6).



Figure 2.2 Topographic map of the Konya Plain

(Map background - https://commons. wikimedia.org/wiki/File:Konya_plain_ topographic_ map-blank.svg; Inset - https://commons.wikimedia.org/wiki/File: Konya_in_Turkey.svg)

2.1.2 **Chronology and stratigraphy**

Çatalhöyük East is an Early Central Anatolian Neolithic site whose duration extends over phases II and IIIa of the proposed regional chronological sequence (Özbaşaran and Buitenhuis 2002: Table 2). The phase ECA II is also known from excavations at sites such as Canhasan III near Karadağ in the Konya plain (French *et al*. 1972), Aşıklı Höyük and Musular to the east in Cappadocia (Esin and Harmankaya 1999; Özbaşaran 1999) and Süberde and Erbaba to the west in the Lake District (Bordaz 1973; Bordaz and Bordaz 1978). It starts at around 9000 BC, before the end of the PPNA, and covers the whole of the PPNB of the Levant; phase ECA IIIa ends at around 6600 BC (Table 2.1; Fig. 2.3).

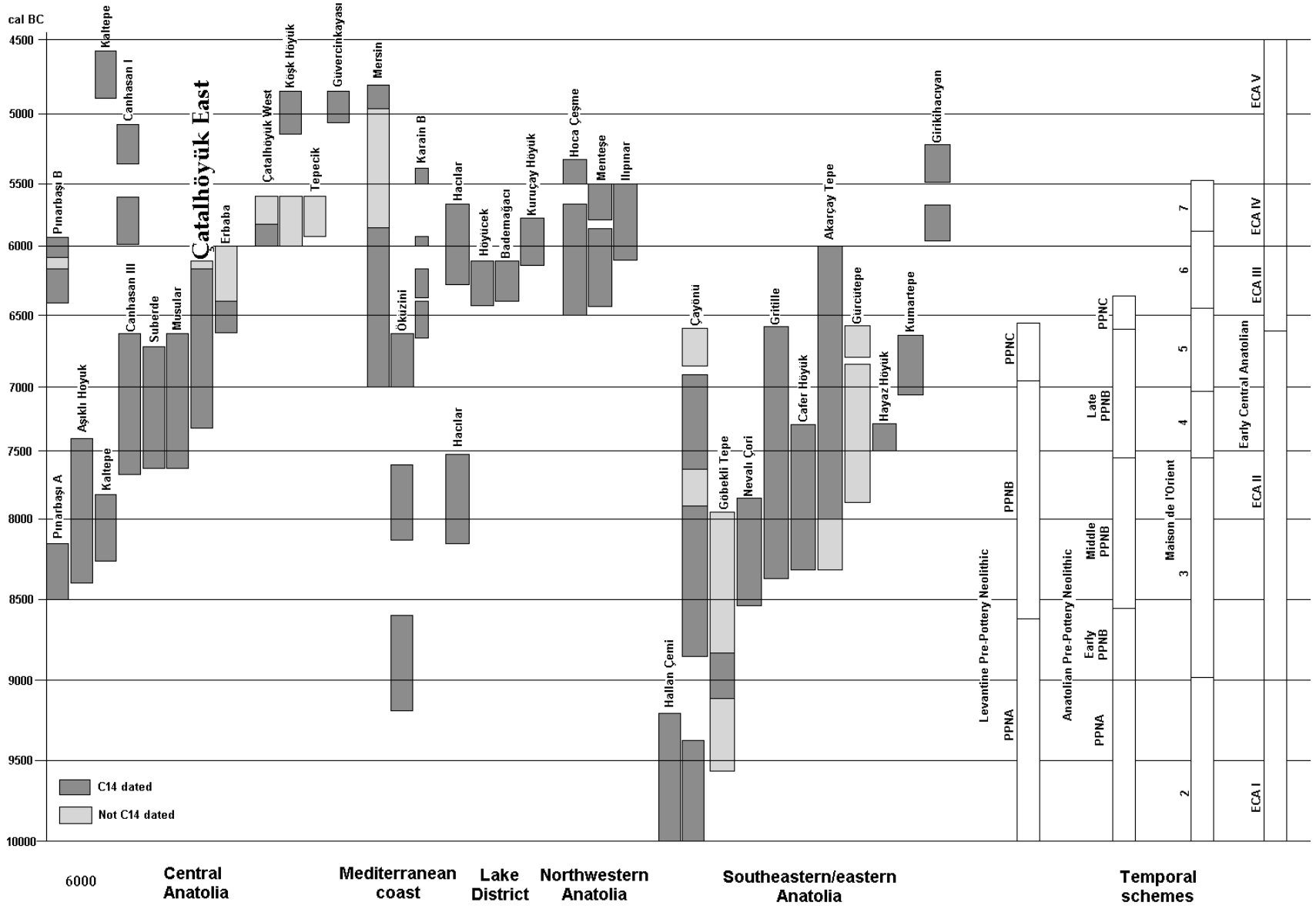


Figure 2.3 Chronological sequence for Anatolia from *c*. 10,000 to 4500 cal. BC (after Hodder 2005: Fig. 1.5)

Early Central Anatolian (ECA) chronological scheme			
Phase	**Time period**	**Culture period**	**Archaeological sites**
ECA I	Younger Dryas - *c*. 9000 cal. BC	Epipalaeolithic	
ECA II	*c*. 9000 - late 8th millenium cal. BC	Aceramic Neolithic	Aşıklı Höyük, Musular, Canhasan III
ECA III	late 8th millenium cal. BC	Neolithic (Early and Late)	Çatalhöyük East
ECA IV	6000 - 5500 cal. BC	Early Chalcolithic	Köşk Höyük, Tepecik, Çatalhöyük West
ECA V	5500 - 4000 cal. BC	Middle Chalcolithic	Güvercinkayasi

Table 2.1 Central Anatolian chronology (after Özbaşaran and Buitenhuis 2002: Table 2)

Early to middle occupation levels at Çatalhöyük East (Pre-Level XII.E-Level VI.B/South G-N), which are the focus of this study, have been dated to 7400-6600/6500 cal. BC (Cessford *et al*. 2005), overlapping with the later Levantine Pre-Pottery Neolithic B period (PPNB). In terms of individual occupation phases, Pre-Level XII (D-A) is dated *c*. 7400-7000 cal. BC ('aceramic phases'); Levels XII-VI are dated *c*. 7000-6600 cal. BC ('ceramic phases'), while late Neolithic Levels V-II are dated *c*. 6600-6000 cal. BC (Fig. 2.4). After *c*. 1200 years of continuous life at the Çatalhöyük East settlement, the focus of occupation moved to the West Mound (Cessford 2001; Cessford *et al*. 2005).



Figure 2.4 Occupation levels at Çatalhöyük East (after Hodder and Cessford 2004: Fig. 1)

The ‘Level’ system of relative chronology at Çatalhöyük was introduced in the initial excavations conducted by James Mellaart in 1960s (see below). Within the then excavated area, Mellaart defined fifteen separate superimposed building Levels numbered 0 (top) to XIII at the near-bottom of the mound (expanded in deep sounding in 1999 - Farid 2007) and the Level-association was used to mark a location of an excavated building within a ‘stack’ or ‘column’ of buildings (Farid 2007, 2008). In a horizontal perspective, buildings with abutting walls or neighbouring positions were understood as part of the same Level. In the new excavations, buildings were correlated with ‘Mellaart Levels’; however, it has become clear that buildings and occupation floors assigned to the same level were not necessarily all constructed at the same time (and perhaps not always occupied at the same) and, across the site, different areas were occupied at different times (Farid 2008). This, and other stratigraphic problems were tackled by conducting a thorough review of the Mellaart Level system against the results from new excavations, and a new phasing system was introduced in 2008 which specifies the excavated area and the phase within the area (Farid 2008). The new system is used as the basis for a large-scale radiocarbon dating programme that is currently under way (Bayliss and Farid 2007; Bayliss *et al*. in press/2013). Table 2.2 links the Mellaart Levels to corresponding phases in the ‘new’ system; both old and new phase names are referred to throughout this study.

Mellaart Level	**Hodder phase**	**Hodder phase**
South (inc. Mellaart) area	*South (inc. Mellaart's) area*	*North/4040 (inc. BACH) area*
I	South T	North J
II	South S	North J
III	South R	North I
IV	South P	
V	South Q	North H/I
VI.A	South O	North ?G
VI.B	South N	North G
VII	South M	North ?F
VIII	South L	North F
IX	South K	
X	South J	
XI	South I	
XII	South H	
Pre-Level XII.A to Pre-Level XII.E	South G	

Table 2.2 Correlation between the two stratigraphic systems - Mellaart Levels and Hodder phases (the North area sequence is preliminary; after Farid 2008)

Several archaeological sites have been documented in Central Anatolia which, chronologically, more or less overlap with the early-mid Neolithic occupation of Çatalhöyük (e.g. Özdoğan 1999; Gérard and Thissen 2002); all are situated at considerable distances from Çatalhöyük (cf. Gérard 2002: 343; see Section 2.2.3), and regional survey suggests that Çatalhöyük East was, for much of its life, a single large site in the Konya plain and that it, in a way, dominated the area (Baird 2002, 2005). A very small number of sites has been substantially excavated, as is the case at Aşıklı Höyük and Çatalhöyük, and only some contain at least one completely excavated building (Cutting 2005), while very few of them have published data on subsistence-related aspects. The available archaeobotanical information on Central Anatolian Neolithic sites are summarised in Section 2.2.3.

2.1.3 **History of excavation**

British archaeologists James Mellaart and David French undertook surveys of Anatolian Plateau in 1950's with other colleagues from the British Institute in Ankara (Mellaart 1959). They discovered the site of Çatalhöyük in 1952 and recognised the importance of the East Mound, which rose to 15 m above the surrounding plain, extended over a large area, and showed traces of mudbrick buildings and Neolithic pottery on the surface (Mellaart 1967: 27). At the time, no evidence was available for the development of the early Neolithic settlements outside Fertile Crescent. Between 1957 and 1960, Mellaart excavated at Hacilar, west of Burdur on the Anatolian Plateau, where he discovered remains from the Aceramic Neolithic (late 9th to mid-8th millennium cal. BC) and late Neolithic to early Chalcolithic occupation (late 7th to earlier 6th millennium cal. BC). He was hoping to find another site on the Anatolian Plateau that would 'fill in the gap' between the Aceramic and late Neolithic occupation at Hacilar (Mellaart 1967: 30), and therefore started excavations at Çatalhöyük in 1961, which continued until 1965. He soon published reports that raised widespread interest in the site; the most prominent features were its size – 13 ha of a large and densely packed Neolithic 'town' – and spectacular wall paintings and other elaborate art uncovered inside the houses (Mellaart 1962, 1963, 1964, 1966). In Mellaart's opinion, 'the wealth of material produced by Çatal Hüyük is unrivalled by any other Neolithic site' (Mellaart 1967: 22).

In 1993 excavations were renewed with an international team of archaeologists led by Ian Hodder, aiming to present a more detailed picture of the people that inhabited the site and their way of life (Hodder 1996). The project has included site excavation, archaeological field

survey of the Konya plain (Baird 2002, 2005) and an off-site palaeoenvironmental investigation (Konya basin palaeoenvironments - KOPAL) (Roberts *et al*. 1996, 1999; Boyer *et al*. 2006). From 1993 to 1995 pre-excavation work (i.e. surface survey and geophysical prospection) was carried out in order to obtain as much information as possible on the surface distributions of artefacts and architecture, and to provide guidance for subsequent excavations, especially concerning the location and stratigraphy of Mellaart's excavation area in the south part of the mound (R. Matthews and Hodder 1993; Hodder 1994).

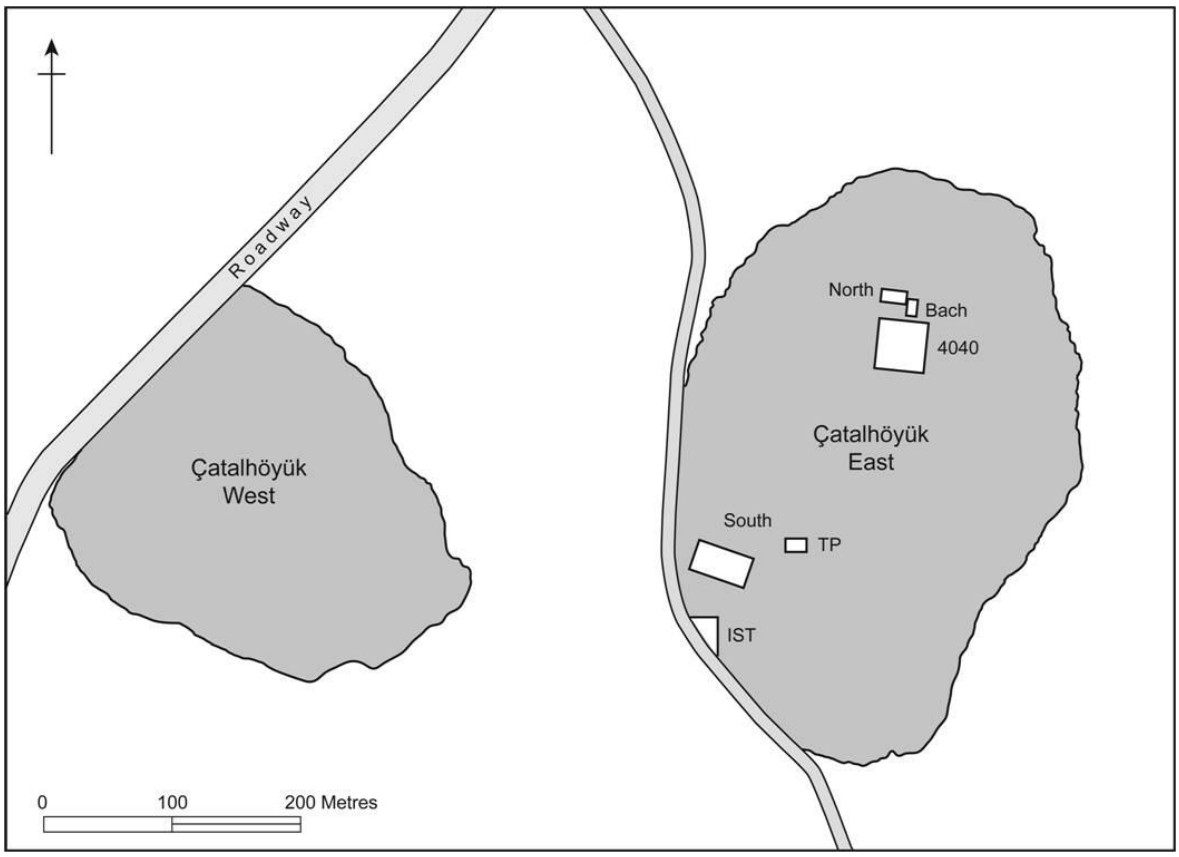


Figure 2.5 Excavation areas at Çatalhöyük East (after Bogaard *et al*. 2009: Fig. 2a)

In 1995 some of the Mellaart's trenches in the South Area of the East mound were re-opened and, at the same time, excavation commenced in the North Area (R. Matthews 1995). The aim was to undertake parallel excavations in both 'submounds' of the East Mound, in the areas designated North and South, the South Area encompassing Mellaart's previous excavation area and, adjacent to it, the Summit Area. The excavations in the South Area between 1995 and 1999 were focused upon a 20x20 m section investigated by Mellaart in the 1960s. The main intention was to explore the earliest phases at the site and to reach natural soil, which was accomplished in 1999 by deep sounding. In summary, 15 Neolithic

occupation levels were investigated, with five phases of Aceramic Neolithic (corresponding to Mellaart's Pre-Level XII levels; Table 2.2) at the base of the mound (Farid 2007). In the North Area, Building 1 and Building 5 were excavated in the period 1995-1999. Between 1997 and 2003 Building 3 was excavated in an area designated as BACH (Berkeley Archaeologists at Çatalhöyük) in the north part of the Mound (to the south-west of the Building 1 and Building 5 excavations). From 1995 to 1999 the KOPAL team worked both on- and off -site: sedimentological cores were taken around the East and the West Mounds and excavations carried out in the North Area (a strip from the North Area downslope, towards the edge of the Mound) and to the north of the East Mound, beyond its visible edge (a trench in a present-day agricultural field - Roberts *et al*. 1996, 1999; Boyer *et al.* 2006). Figure 2.5 shows the location of each excavation area; other areas shown were opened subsequent to the initial campaign of renewed excavations in the 1990s: TP (Team Poznan) in 2001, 4040 area in 2003 and IST (Istanbul University) in 2004.

2.1.4 **Summary of archaeological features**

The Çatalhöyük mounds are the result of long-term superimposed rebuilding of mudbrick structures, in some cases featuring individual buildings reconstructed over an extended number of 'generations' (Mellaart 1967; Hodder 1996; Düring 2005; Hodder 2006). The East Mound consists of two submounds - the southern one being higher and larger than the one at the northern end. Mellaart's work focused on the south-west part of the East Mound (the 'south mound'), where he discovered 15 successive building levels. In different levels he unearthed a total of 160 abutting rectilinear mudbrick structures, with walls separated by only a few centimetres from those of neighbouring houses (Mellaart 1967). An identical situation was encountered in renewed excavations and surface scrapings (R. Matthews 1995; Hodder 1996). Also, no streets or alleyways have been traced between the houses except in the uppermost levels (Düring 2001, 2005, 2006); the open areas present at a few locations were used for discarding rubbish (Mellaart 1967; Hodder 2006: 102-104). New houses were rebuilt on top of old ones, though the space where an old house stood was sometimes left open and was used for rubbish discard (midden) area from surrounding buildings, as a penning area and/or as a location for intermittent outdoor activities. The 15 identified superimposed building horizons/levels of occupation spanning over a thousand years resulted in the formation of a mound/tell (Hodder 1996, 2005).

Buildings differ in size within and between occupation levels/phases. Available calculations of the internal area mostly refer to buildings excavated by Mellaart in Levels VIII-II/South L-S where relatively large areas of the settlement mound have been uncovered (Düring 2001, 2006; Cutting 2005). According to these, the internal sizes for a large majority of buildings range from 12 m² to 38 m² (Düring 2006: 171, Figure 6.11) or 19 m² to 32 m² (Cutting 2005: 51); in both cases the average size is about 25 m². There are, however, examples of larger units (usually with a greater number of rooms per building) in early-mid Neolithic levels, such as Building 1 (Level VII-VI/North G, discovered in the new excavations and included in this study) with the 42 m² floor surface; hence the upper end of the building size range for this sequence can be higher. Based on the available calculations, the average building sizes do not vary significantly between the early-mid Neolithic levels (see Düring 2001: Table 1), but units seem to increase in size towards the upper levels (e.g. up to the average of 59 m² in Level II - Düring 2001: Table 1; but see Cutting 2005 for lower average figures, e.g. 32 m² for Level II/South S). Each house contains a main room (of 5x4 m on average) for living and activities such as tool-making, cooking, eating, sleeping, and usually at least one small side room, used for food storage (in bins/basins, baskets etc) and some food preparation activities (Cutting 2005; Atalay and Hastorf 2005, 2006; Hodder 2006: 119-122). Inside the main room, common features are ovens, hearths, art and symbolic objects (e.g. reliefs, wall paintings, *bucrania*), and raised platforms often with (sometimes multiple) human burials deposited underneath; the one or more side rooms are fitted with bins and basins (Mellaart 1967: 54-62; Hodder 2006: 119-122). The configuration of the houses and the location of the internal furnishings are strikingly standardised throughout the site's occupation (Düring 2006). The central room was visually divided unevenly into a larger 'clean' area (usually to the north), comprising the platforms, human burials and art/symbolic installations, and a smaller 'dirty' area, with residues of cooking and food preparation, fuel use and crafting (e.g. knapping) (Matthews 2005a; Hodder 2006). The clean area seems to have had a special social and ritual role, as it contains wall paintings, plastered benches, pillars mounted with plastered wild cattle skulls and horns and so on (Russell and Meece 2005; Last 2005b), and may have functioned as a relatively public area of the house (Bogaard *et al*. 2009; Twiss *et al.* 2008, 2009).

The architectural evidence from the early-mid Neolithic occupation generally suggests that access to the house interior was from the roof, using a ladder through an opening normally situated above an oven and through which smoke was released (and which could have served

as a light shaft); no evidence for window openings or external doors had been found, although, since walls are often preserved 'only' up to about 1.4-1.5 m above the floor level, the existence of highly positioned windows cannot be excluded (Mellaart 1967; Cutting 2005; Hodder 2006). Flat roofs have been assumed based on the mode of entry (via ladder from 'above'), ethnographical examples (e.g. Ertuğ-Yaraş 1997; Fairbairn *et al*. 2002; Biçakçi 2003: 386) and sections of collapsed roof recovered from Building 3, which also showed traces of common domestic activities in the form of fragments of e.g. hearth floor and plant and animal remains, pointing to the likely use of roof as a working (and communication) area (Stevanović and Tringham 1998: 3; Matthews 2005a, 2010). However, some of the burned buildings discovered in recent excavations of the South Area (Level VI/South N-O) seem to contain evidence (floors, walls, wooden beams) of an upper storey (Buildings 79 and 80 - Hodder 2009).

Walls were built of sun-dried mudbrick fused with pisé (mortar), made of clay or midden-type material, and supported by wooden posts (Mellaart 1967; Cutting 2005). In early levels, bricks were made of dark silty clay (up to Level IX/South K) and they are subsequently replaced by bricks made of light-coloured (reddish) loamy clay, while bricks made of sand also occur (Matthews 1996; Doherty 2007; Doherty in press/2013). The material for brick-making was of local origin (Love 2012; Doherty in press/2013) and is tempered with reeds, grasses and chaff from cereal spikelets (Stevanović and St. George 2005; Bogaard *et al*. 2008; Ryan 2011, in press/2013). Timber from collapsed/abandoned buildings was commonly re-used as building material or fuel (Asouti 2005b). Oak was the dominant source of timber from Level Pre-XIIA/South G (Asouti and Hather 2001; Asouti 2005b). Walls and floors of buildings were regularly plastered, on an annual or even monthly basis (Matthews 2005a, 2010); deposits discovered in the deep sounding trench (Space 181) appear to contain evidence of burning of lime to create plaster (Matthews 2005a; Cessford 2007a).

Recent excavations have discovered that floors were cleared of most artefacts before (planned) abandonment, and so not many of them have been found *in situ*; in contrast, midden areas of rubbish disposal (for which old/abandoned buildings are sometimes also used) have produced vast amount of material including chipped and ground stone, pottery fragments, beads, worked bone, clay balls, figurines (e.g. Martin and Russell 1996; Hodder 1999: 159; Hodder and Cessford 2004), as well as floral and faunal remains (Fairbairn *et al*. 2005a; Russell and Martin 2005). Several burnt buildings unearthed in the course of new

excavations (e.g. Buildings 1, 52, 77) have offered a more detailed record of the 'contents' of houses, particularly in terms of animal and plant remains of food preparation and consumption, and charred wood and other fuel sources (Fairbairn *et al*. 2005a; Twiss *et al*. 2008, Bogaard *et al*. 2009, in press/2013).

2.2 Macro-botanical and faunal evidence

The following sections summarise the results of previous archaeobotanical and faunal analysis at Çatalhöyük relevant to the present study. The final section provides a brief overview of subsistence-related studies in the wider region, including the sites earlier than Çatalhöyük (Pınarbaşı A, Boncuklu, Aşıklı Höyük) or those that partly overlap with its early-mid sequence (Musular, Canhasan III, Süberde, Erbaba).

2.2.1 Previous archaeobotanical research at Çatalhöyük

During the 1960s' excavations systematic sampling and flotation were not employed, and the first plant remains analysed from Çatalhöyük represent chance finds of concentrations of charred material from burnt houses, where (crop) remains were found *in situ* in clay storage bins, or as cashes of (wild) seed in other deposits (Helbaek 1964; Fairbairn *et al*. 2005a, 2007), as well as wooden objects and remains of fabric (Mellaart 1967). The first analysis of plant remains was carried out by Hans Helbaek, who identified some of the major crop types confirmed by later work: emmer (*Triticum dicoccum* Schrank), einkorn (*T. monococcum* L.), bread wheat (*T. aestivum* L.), naked barley (*Hordeum vulgare* L. var. *nudum*), pea (*Pisum sativum* L.) and bitter vetch (*Vicia ervilia* (L.) Willd.). He also recorded some wild taxa such as small-seeded crucifers (*Capsella bursa-pastoris* (L.) Medicus and *Erysimum sisymbrioides* C.A. Mey, some found in a bin), wild vetch (*Vicia noeana* Reut ex. Boiss) and two grass-types (*Taeniatherum* Nevski and *Eremopyrum* (Ledeb.) Jaub. & Spach.), 'small heaps' of almonds (*Amygdalus* L.) and acorns (*Quercus* L.), as well as finds of pistachio (*Pistacia* L.), hackberry (*Celtis* L.) and sea club-rush tubers (*Bolboschoenus maritimus* (L.) Palla) (Helbaek 1964) (for detailed list see Fairbairn *et al*. 2005a: Table 8.1). The presence of wetland plants led Helbaek to conclude that crop fields were irrigated. Furthermore, Helbaek's impression was that crop husbandry at Çatalhöyük was in its well-developed stage in terms of domesticated forms (with a 'long prehistory somewhere else'), and, based on large-scale crop

storage, that it was of considerable importance in the site's economy (Helbaek 1964). Todd (1976) suggested that most of the area within a 5 km radius around the site would have been suitable for growing cereals (while some poorly drained areas could have been used for grazing), and that the cultivable land could have supported a relatively large population (Todd 1976: 124).

Within the present project (Hodder 1996, 2005a, in press/2013) systematic archaeobotanical sampling of every excavated context ('unit') has been carried out, and flotation and laboratory procedures developed and refined (Ağcabay *et al*. 2003; Hastorf 2005; Bogaard *et al*. 2005a). The progress and results over the years have been presented in Çatalhöyük Archive Reports produced at the end of each excavation season (http://www.catalhoyuk.com). More detailed accounts of Çatalhöyük archaeobotany and interpretation of the results have been published in journals and the site monographs (Fairbairn *et al*. 2002, 2005a; Fairbairn 2005; Cane *et al*. 2012; Bogaard *et al*. in press/2013). The most relevant to this study is the work completed by Fairbairn and Fairbairn *et al*., which includes the material retrieved from early-mid levels at Çatalhöyük East and presents detailed analysis of 77 archaeobotanical samples from 75 units (out of the 355 units selected for detailed analysis by the specialists working at the site) excavated in 1995-1999 (see Ch. 3). Their results are referred to throughout the thesis, as well as, to some extent, the results produced by Cane *et al*. for Building 3 and Bogaard *et al.* for mid-later occupation of the site.

Archaeobotanical and zooarchaeological data from the earliest levels of the settlement onwards point to the cultivation of a range of cereals and pulses, as well as herding of sheep and goat (see below), combined with gathering of wild plants and hunting of wild animals, including cattle (*Bos primigenius*). Of crops, the most abundant are remains of cereals - wheat and barley, and pulses - peas, lentils, bitter vetch; they were grown, processed, stored and consumed as food and/or fodder. Some wild species were also gathered for food or fodder, such as almonds, plums, pistachio, hackberries, tubers, acorns and wild mustard seeds (Fairbairn *et al.* 2002, 2005a, 2007; Russell and Martin 2005; Bogaard *et al.* in press/2013).

The previous archaeobotanical work provided detailed insight into the remarkable diversity of crop and wild flora at Çatalhöyük; discussed their state of preservation, abundance and frequencies; revealed similarities and differences between botanical composition of different excavation contexts; identified the importance of dung as a major source of plant material and

discussed multiple aspects of plant use in the Konya plain (Fairbairn *et al*. 2005a: 137). It is owing to this research that an exceptionally good picture of exploitation of plant resources at Çatalhöyük has become available, and the present study seeks to build upon it by focusing on, and expanding several important aspects discussed in the preceding work.

2.2.2 **Overview of the faunal assemblage**

The Çatalhöyük zooarchaeological assemblage shows predominance of domestic sheep and goat (primarily sheep) across the deposits and through the whole of the site's occupation; their proportions relative to other taxa rise sharply towards the later phases, while the high ratio of sheep to goat remains the same throughout (Russell and Martin 2005; Russell in press/2013; Russell *et al*. in press/2013). The only exception to the overall sheep prevalence is the off-site KOPAL area where sheep/goat are in the minority, and cattle and some other wild animals are dominant, probably representing 'special' (feasting-related) deposits (Russell and Martin 2005).

Apart from dog, sheep and goat are the only domesticates at the site. Contrary to the results of earlier analysis of animal remains from Çatalhöyük (recovered in Mellaart's excavations), the evidence from new excavations argues against cattle herding (Russell and Martin 2005); only in the latest occupation a decrease in the size of cattle has been noted, hinting at possible domestication (Russell *et al*. in press/2013). Wild cattle is the second most commonly represented taxon, followed by equids, wild boar and deer and a range of other wild taxa (e.g. foxes, hares, badgers) that might have contributed to the site's food (meat) economy.

Contextual and formal analysis of faunal remains suggests that sheep and goats represented a regular source of meat. For the early-mid Neolithic levels milk does not appear to have been an important/primary product and the major source of animal fat may have been marrow and bone grease (Russell and Martin 2005; Evershed *et al*. 2008). The cattle body part distribution suggests that whole carcasses were brought back to the site (unlike e.g. pigs and deer). Cattle contributed large amounts of meat which seem to have been mainly consumed as part of special 'feasting' events (Russell and Martin 2005). The presence/use of cattle horns and scapulae (and other body parts) in special deposits and installations suggests that they played an important symbolic and ritual/ceremonial role (Russell and Martin 2005; Twiss *et al*. 2008; Russell in press/2013).

Numerous bird remains were also found at Çatalhöyük and they mainly belong to wetland species that may have been targeted more for their feathers than for meat (Russell and McGowan 2005). The eggshell assemblage is extraordinarily large and indicates the importance of eggs in the diet and/or the extraction of egg yolk for pigment binding (Sidell and Scudder 2005). Micro-faunal evidence points to house mouse as the most common species; other small mammals present at the site include weasel, hedgehog, vole, shrew, and bat (Jenkins 2005). In the early occupation levels (Pre-Level XII.D-A and Level XII/South G-H) a large quantity of amphibian remains is found, but the numbers fall sharply after Level XII/South H perhaps suggesting an environmental change towards drier conditions (Jenkins 2005). The study of shells (Reese 2005) revealed the presence of local freshwater shells (mainly of the genus *Unio*), sea shells from the Mediterranean (e.g. *Dentalium*) and the Red Sea, and land snails (probably naturally present in the deposits). Freshwater shells were a likely food source, while they were also used as raw material for making ornaments, and as pigment containers. Marine shells were transported from long distances and also used to make ornaments (Reese 2005).

2.2.3 **The evidence from the wider region**

For Central Anatolia, data from past and recent/on-going research projects have offered valuable insight into the plant and animal exploitation strategies in the period pre-dating, and in some cases partially overlapping with the Çatalhöyük early-mid Neolithic occupation, providing a context for the diverse spectrum of subsistence practices suggested for Çatalhöyük. The evidence presented here derives from several sites in the Konya plain which are spatially and chronologically close to Çatalhöyük (Fig. 1), and for which at least some relevant data were available (Table 2.3). The evidence indicates highly diversified economic strategies, from hunting/gathering (Pınarbaşı A) to cultivation and foraging without herding (Boncuklu) to cultivation and herding (Aşıklı Höyük, Çatalhöyük).

Overall, domestic cereal and pulse cultivation seem to have been widespread and established practice, supporting other lines of evidence of more or less sedentary life (e.g. architectural, faunal) at the beginning of the early Neolithic in Central Anatolia. There were local variations in the level of crop cultivation, as well as variable levels of exploitation of cereals *versus* pulses, and of crop types within the two groups, though this situation may be a consequence of significant differences in preservation potential and sampling strategy, or

complete lack of sampling (Asouti and Fairbairn 2002). Locally available wild resources played an important role and were a regular supplement to crops. At Çatalhöyük East a picture emerges of continuity in the choice of plant resources and in the strategy of their procurement/production, though a change in the spectrum of used plants has been noted pointing to its greater diversity in the earliest occupation levels (Fairbairn *et al*. 2005a; Bogaard *et al*. in press/2013).

	Pınarbaşı A	Boncuklu Höyük	Aşıklı Höyük	Musular	Canhasan III	Çatalhöyük	Suberde	Erbaba
cereals, pulses		x	x	x	x	x	x	x
fruits, nuts	x	x	x	x	x	x	x	x
sheep	wild	(wild)	wild/ managed	wild	wild	domestic	domestic	domestic
goat		(wild)	wild/ managed	wild	wild	domestic	domestic	domestic
cattle			wild	wild	wild	wild		domestic

Table 2.3 Summary of the subsistence evidence from Central Anatolian Neolithic sites (see text for references)

Faunal assemblages show a more complex picture of the animal-based economy in the early-mid Neolithic of the region (up to mid-7th millennium cal. BC), including broad-spectrum hunting, focus on wild sheep hunting and/or herding, wild cattle hunting, and wild/domestic caprine herding. This may reflect stages in development of, and/or differences between the communities and through time, in animal management methods and efforts at maintenance/modifying of animal resources (e.g. Zeder 2011). For example, at the two sites that so far yielded the most abundant and best studied animal bone assemblages - Aşıklı Höyük and early-mid Çatalhöyük East - there appear to be no major changes in the management of animal resources (primarily sheep and goat) over time, indicating a reasonably stable procurement strategy capable of satisfying the needs of the community (Martin *et al*. 2002; Russell and Martin 2005).

Pınarbaşı A

Pınarbaşı A is a late Epipalaeolithic/early Neolithic 9th millennium BC small seasonal hunting and/or herding camp located at the base of a cliff at the foothills of the Karadağ volcanic massif, *c*. 25 km south-east of Çatalhöyük (Watkins 1996; Asouti 2003; Baird 2005). Temporary habitation structures in the form of light shelters made of reed are

suggested by the phytolith data (Özbaşaran 2011: 105). Systematic sampling and flotation yielded well preserved animal bone, whereas charred plant remains and wood charcoal were sparse (Asouti 2003). Archaeozoological analysis indicates hunting of a range of mammals (e.g. wild sheep, auroch, red deer, equids, wild boar), birds and fish (Martin *et al*. 2002; Carruthers 2003); charcoal evidence reveals predominance (and similar relative proportions) of few tree and shrub taxa - almond, rosewood and pistachio, and the presence of several other taxa (Asouti 2003: Table 3).

A combination of animal bone and charcoal data provided clues for past vegetation around early Neolithic Pınarbaşı, suggesting a very diverse picture of forest and wetland habitats in the relative vicinity of the site, including woodland steppe (home to pistachio, almond and hackberry), grassland, and riparian forest (Asouti 2003).

Boncuklu Höyük

The settlement mound is located on an elevated marl rise 9 km north of Çatalhöyük and is dated to mid-8th millennium BC (Baird 2006-2010; Özbaşaran 2011). The site has been under investigation since 2006 and, so far, finds of wild plants, domestic cereals and a diverse assemblage of wild animal remains have been discovered, and the analysis is under way (A. Fairbairn, pers. comm.).

Aşıklı Höyük

The early Neolithic aceramic village is located some 150 km from Çatalhöyük to the east, on alluvial deposits in the narrow valley of the Melendiz river. It was occupied between about 8500 and 7400 cal. BC and, apparently, abandoned a short time before the beginning of settling at Çatalhöyük (Esin and Harmankaya 1999). The excavations at the site are ongoing (http://www.asiklihoyuk.org).

The published environmental data derive from the 1989-2000 excavation seasons. Plant remains were retrieved through flotation; they were often poorly preserved. Evidence of domesticated plants in the form of charred remains of einkorn, emmer and free-threshing wheat, two-row hulled barley, and naked barley were recorded, as well as pulses - bitter vetch, lentils and peas (van Zeist and de Roller 1995). There is also evidence of crop processing activities (documented by the presence of cereal chaff). The weed assemblage points to rain-fed cultivation, possibly on raised surfaces along the river course and/or on dry

areas in the valley, presumably close to the settlement. Wild fruits and nuts were also gathered, including hackberry, pistachio and almond (van Zeist and de Roller 1995).

The faunal assemblage presents evidence of management/herding of wild sheep/goat (mainly sheep), and minor use of other wild taxa such as cattle, equid, boar/pig (Buitenhuis 1997; Martin *et al*. 2002). The results of micromorphological analysis show evidence of dung burnt as fuel, as well as uncharred dung in an open space perhaps indicating penning of animals within the settlement (Matthews 1998: Appendix 2; Gérard and Thissen 2002: 209).

In summary, exploitation of locally available resources through the cultivation of cereals and pulses, wild plant gathering and herd management (perhaps including penning) of sheep and goat appear to have been the major subsistence practices at the site. Given the size and longevity of the settlement, it is suggested that food procurement/production was, at least to certain extent, a socially 'regulated process' (Buitenhuis 2002).

Musular

This is a small flat site across the Melendiz river from Aşıklı Höyük dated to mid-8th and 7th millennium cal. BC (Özbaşaran 2000, 2011). In its earlier, pre-pottery phase (followed by a later, pottery phase) is probably contemporary with the uppermost horizon at Aşıklı; indeed, the single mudbrick structure discovered from this phase has a similar layout, size and set of internal features to the non-domestic ('special') buildings at Aşıklı and suggests that the site was founded by the same community (Özbaşaran 1999, 2000, 2011).

It terms of animal remains, it appears that, in contrast to the initial impression based on a small sample (Özbaşaran 2000), wild cattle dominate the assemblage (especially the midden deposit); (wild) sheep and goat are present in much lower quantities, unlike the situation at Aşıklı, where wild sheep dominate (Buitenhuis 1997; Martin *et al*. 2002; Duru and Özbaşaran 2005). Other wild taxa, such as equid, cervids, and wild boar occur in small proportions (Duru and Özbaşaran 2005). The abundance of cattle remains at Musular, and their association with the 'public' space, are understood as potential evidence of communal/large-scale (ritual) consumption of cattle (Özbaşaran 2011: 110); based on the similarities in aspects of non-domestic architecture, it is further suggested that the site was part of Aşıklı's 'social landscape' and that it had a special, symbolic role as a place where cattle post-hunting

activities - butchering, communal consumption(/feasting) and, ultimately, discard - took place (Duru and Özbaşaran 2005).

The botanical record (study of which is ongoing) attests to the presence of emmer, bread wheat, naked barley, lentils and chickpea, and a range of wild/weed taxa, overlapping with the evidence from Aşıklı (Özbaşaran 2000; Asouti and Fairbarn 2002: Table 1).

Canhasan III

The tell site sits on the May alluvial fan, 70 km to the south-east from Çatalhöyük, near the town of Karaman in the foothills of the Taurus mountains; it was excavated in 1969-1970 (French *et al*. 1972). A deep sounding trench revealed seven major habitation levels - complexes of mudbrick structures, with wall and floor surfaces coated with mud plaster and sometimes painted in red. The lower levels of the deep sounding were dated to 7650-6600 cal. BC (Thissen 2002).

Plant and animal remains were collected from the deep sounding (approximately 3 m in depth) and wet-sieved, but have not been studied in detail. A preliminary report on plant remains notes the presence of domesticated cereals and pulses (French *et al*. 1972; Asouti and Fairbairn 2002: Table 1) - einkorn, emmer and bread wheat, naked barley, two-row hulled barley, naked barley, peas, lentils and bitter vetch. In addition, some wild taxa seem to have been in use, such as hackberry, wild cherry and wild grape. Use of dung as fuel has been suggested based on the composition of a concentration of plant remains from an oven. Preliminary examination of faunal assemblage suggested that wild cattle were common while sheep, goat, red deer, equid and pig were also present (French *et al*. 1972). It appears that the economy heavily relied on crop cultivation and hunting, though, since no evidence of culling pattern is available, domestic herding cannot be excluded.

Suberde

The small mound in Lake District (by the Suğla Lake), some 100 km to the west from Çatalhöyük was excavated in 1964-1965, and the early (aceramic) Neolithic documented in Levels II and III (Bordaz 1973; Duru 1999); Level III was dated to *c*. 7460-6770 cal. BC (Thiessen 2002) overlapping with earliest levels at Çatalhöyük. The remains of floors and mudbrick walls in these levels pointed to the presence of rectangular structures; some structures had round clay basins cut in the floor.

A large number of animal bones was retrieved; the presence of domesticated dog and large-scale hunting of sheep, goat, pig, cattle and red deer were inferred (Bordaz 1973). The wild/domestic status of sheep is not clear from the previous analysis (Payne 1972); new investigation suggests that caprines were potentially domesticated, though they remain relatively large compared to the Çatalhöyük record, perhaps due to continued inbreeding with the wild population (Arbuckle 2008).

Botanical remains were not systematically collected; only a small quantity of pollen grains were recovered, and identified as derived from (domestic) cereals (Bordaz 1973). Due to the lack of sampling, no charred remains have been encountered (Bordaz 1973); the four clay impressions represent the only evidence and they belong to wheat, barley, grass pea and pistachio (Asouti and Fairbairn 2002: Table 1).

Erbaba

Some 75 km from Çatalhöyük to the west, another mound in the Lake District (on the banks of the Beyşehir River), set on a natural hill, was excavated intermittently in the period 1969-1977; Level III was assigned to the early Neolithic (Bordaz 1973; Bordaz and Bordaz 1978). Radiocarbon dates from Level III show that the occupation began about 6600/6400 cal. BC (Thiessen 2002), around the time of Çatalhöyük Level VIII/South L. The architectural elements of Level III include buildings with mudbrick walls set on cobble stone foundations which, together with floors were plastered and sometimes painted red; clay benches, decorative pilasters and ovens were documented inside the houses (Bordaz 1973; Bordaz and Bordaz 1978).

Dry sieving and flotation were used to retrieve subsistence information. Domesticated cereals (emmer, einkorn, free-threshing wheat, two-row hulled barley, naked barley) and pulses (lentils, peas, bitter vetch, chickpea and grasspea) appear to have been widely used (van Zeist and Buitenhuis 1983). Analysis of the animal remains suggests that sheep, goat and cattle were domesticated, and that the use of cattle for meat increased over time, relative to the reliance on sheep and goat, which were more exploited for milk and wool (Bordaz and Bordaz 1976). Re-assessment of the material shows a slightly different picture, indicating sheep herding for meat in the early levels, while (a small number of) goats could have been reared for their secondary products; apparently, domestic sheep and domestic cattle herding was practised throughout Erbaba's occupation (Arbuckle 2008).

2.3 Environment

This section summarises data on the present-day Central Anatolian environment and climate and, more specifically, on the southern part of the Konya plain, where Çatalhöyük is located. The current model proposed for the environment at the time of Çatalhöyük is described, followed by relevant information from previous archaeobotanical and wood charcoal analysis. The implications from the palaeoenvironmental data for the study of Çatalhöyük agriculture, and some alternative approaches/models, are discussed in the final subsection.

2.3.1 Present-day environment of Central Anatolia and the Konya plain

The region of Central Anatolia corresponds to the interior part of the Anatolian peninsula and is surrounded by the regions extending along the coasts of the Black Sea, the Sea of Marmara, the Aegean and the Mediterranean. It consists of a high-altitude massif often referred to as the Anatolian Plateau, which can be defined as an extensive area of mainly flat or gently sloping land at altitudes of between 800 m and 1000 m, with extinct volcanoes (e.g. Karadağ, Hasan Dağı, Melendiz Dağı) and mountain chains (Taurus, Anatolides, Pontic mountains) rising to over 2000 m asl. Large water basins occur in the depressions, including permanent lakes, such as the salt lake of Tuz Gölü in the Sultansazlığı plain to the north and freshwater Beyşehir Lake in the Lake District to the west; Konya Lake, in the centre of the Plateau, disappeared by the end of the Pleistocene. Shallow seasonal lakes also occur - Akgöl (formerly permanent), Suğla and, until recently, Hotamiş Lake, which dried about a decade ago (Erkal 2006). The Kızılırmak and the Sakarya rivers represent major water courses flowing into the Black Sea, while rivers forming the Konya basin dry out before they reach the sea (Zohary 1973; de Ridder 1965; Driessen and de Meester 1969; de Meester 1970; Driessen 1970; Kuzucuoğlu 2002).

The Konya-Ereğli plain occupies the southern part of Central Anatolia, and is flanked by volcanic Cappadocia to the east and the Lake District in the highlands to the west (Fig. 2.2; also, Kuzucuoğlu 2002: Fig. 2). The varied landscape of Central Anatolia can be classified within three general zones, all more or less present in the Konya plain: wetlands, highlands, and lacustrine and alluvial plains (Kuzucuoğlu 2002: 39-40).

Wetlands in the form of freshwater marshes occur near freshwater lakes, springs, and rivers (usually towards the edge of alluvial fans). Salt marshes are common around permanent or seasonal salt lakes. The closest wetlands to Çatalhöyük were until recently found around former Hotamiş Lake (Asouti 2003); at present, seasonally wet shallow depressions occur up the Çarşamba stream, towards the Bozkır area to the south (pers. observation).

Apart from the mountains in and surrounding the Konya plain, limestone or volcanic mounds (hillocks) scattered over the plain can also be considered uplands, as they rise up to *c*. 200 m above the otherwise flat karstic areas (Kuzucuoğlu 2002: 40, 52). An east-west oriented sand ridge *c*. 7 km to the south from Çatalhöyük was part of the Pleistocene lake landscape (Rosen and Roberts 2005). Towards the edge of the basin, terraces and limestone and volcanic colluvial slopes lie along the foothills of the mountains. The uplands are covered with forests, though affected by clearance to supply fuel and provide grazing areas; here, any crop cultivation on the thin soils is rain-fed (Kuzucuoğlu 2002; Asouti 2005b; Rosen and Roberts 2005).

The plains of Central Anatolia are vast open areas of varying elevation, shape and size, and represent the bottoms of former lakes, or alluvial fans (of which some occupy former lake basins). Lake-bottom (lacustrine) plains, one of which is the Konya plain, are covered by soils (marls or clay) of varying permeability; where these soils retain surface water, heavy evaporation takes place in warm seasons, eventually leading to salinisation. In general, these areas are not suitable for agriculture and are usually home to steppe vegetation, though there are variations in their quality/arable potential, and some can support rain-fed agriculture (de Meester 1970; Driessen 1970; Kuzucuoğlu 2002).

Alluvial fans form at the mouths of rivers and streams, and are normally located at edges of lacustrine plains of Central Anatolia. The fast-running rivers from the surrounding mountains carry coarse and fine sediments (silts, sands, gravels) and deposit them across the plains (Rosen and Roberts 2005), creating fan-shaped landforms where alluvial deposits are interstratified with lacustrine sediments (Kuzucuoğlu 2002: 51). Depending on the river regime and potential (the amount of water), flooding can occur in the areas of discharge, causing inundation of the lacustrine plains, where water remains on top of the lake marl for an extended period and prevents arable cultivation (de Meester 1970).

The largest alluvial fan in the Konya basin is that of the Çarşamba river, which enters the plain from the uplands to the south and splits into three branches further to the north; geomorphological evidence indicates that a main channel of the river flowed next to Çatalhöyük (i.e. the palaochannel exposed *c*. 500 m south of the site - Roberts *et al*. 1996; Roberts and Rosen 2009). The Çarşamba fan covers an area of *c*. 474 km^2 (Roberts 1995) and the town of Çumra (*c*. 10 km to the south from Çatalhöyük) lies in its centre (Fig. 2.2). As opposed to the general non-arable characterisation of lacustrine basins (see above), at present the Çarşamba fan represents the most important agricultural area in the Konya basin (Driessen and de Meester 1969: 2). The fan is mostly flat; the only raised areas are sand ridges *c*. 7 km to the south from Çatalhöyük, which represent remnants of the old Konya lake shores. Both the fan and the ridges are used for growing cereals and vegetables, and are dotted with isolated oaks stands (Driessen and de Meester 1969; Asouti and Hather 2001; Kuzucuoğlu 2002).

2.3.1.1 **Climate**

The climate of the plain is semi-arid, with dry hot summers (a three-month period of drought) of mean temperatures above 20˚C (maximum often above 35˚C) and cool relatively wet winters, with average temperatures around 0˚C. The annual precipitation occurs predominantly in winter and spring and is very low - it rarely exceeds 300 mm, suggesting that reliable rain-fed farming of cereal and pulse crops is not feasible; an extensive artificial irrigation system provides supplementary water for modern fields. The common winds (northerly and southerly) are dry but can turn into devastating hail storms (de Meester 1970; Driessen 1970; Davis *et al*. 1965-1988; Kuzucuoğlu *et al*. 1998; Rosen and Roberts 2005). In contrast, the mountains bordering the plain (the watershed catchment area) receive up to 1000 mm of rain/snowfall per year and the humidity there is high compared to the basin itself, where it is usually below 50% (Driessen 1970; Rosen and Roberts 2005). Heavy rains and melting of snow in the mountains in spring (April-May) generate high Çarşamba water table and may result in flooding of the lowlands. The potential extent/nature of flooding is, however, poorly understood; based on the documented behaviour of the river far upstream - in the Bozkır area at the foot of the Taurus Mountains receiving high precipitation - it was suggested that, in the past, flooding would have peaked in spring, though rains could have caused small-scale, short flooding episodes throughout autumn and winter (Rosen and Roberts 2005; Roberts and Rosen 2009).

2.3.1.2 **Soils**

A number of geologists and geomorphologists have studied sedimentary sequences and geomorphological features in the Konya plain, and in the vicinity of Çatalhöyük in particular, revealing a variety of soil types and their distribution (de Ridder 1965; Driessen and de Meester 1969; de Meester 1970; Driessen 1970; Roberts 1995; Roberts *et al.* 1999; Boyer *et al*. 2006; Roberts *et al*. 2007; Doherty *et al*. 2007, 2008). The basin floor consists of marl and calcareous clay originating from the Pleistocene Konya Lake that disappeared towards the end of the Würm glacial (de Ridder 1965; Boyer *et al*. 2006; Roberts *et al*. 2007). Overlying these are alluvial deposits of sand, gravel and clay accumulated during the Holocene. In the more humid mountainous zone towards the fringes of the basin, brown forest soils on top of calcareous rocks are the most extensive (de Meester 1970).

The fine-grained alluvial sediments of the Çarşamba fan, similar to the other fans on the Konya plain, have been characterised as clayey, loamy (locally sandy), and loamy over sandy subsoil which, in general, are formed in the lowest areas of flood basins where the groundwater may be close to the surface (de Meester 1970). The soils have been interpreted as backswamp deposits, a regular feature of floodplain environments of meandering river systems which form levees (river banks) that keep flood waters in the flat zone beyond the banks; levee soils tend to be sandy (i.e. coarser than clay) and relatively free-draining (Brown 1997). Alluvial deposits are considered high-quality agricultural land because they have high content of organic matter, are sufficiently wet and easy to till/plough (de Meester 1970; Sherratt 1980; Kuzucuoğlu 2002). However, in the Çarşamba fan, and perhaps the whole Konya basin, the potentially high productivity of the alluvium is understood to be hampered by the high groundwater table resulting from a) impenetrability of the lake marl underlying the alluvium, and b) general lack of natural drainage on the plain (i.e. no surface water exit), which together lead to c) waterlogging of soils in the river catchment (Rosen and Roberts 2005).

The new geomorphological evidence from multiple cores obtained in the vicinity of Çatalhöyük shows that the Konya Lake marl is of variable thickness around the site, and is interbedded with underlying Pleistocene sand, which implies the existence of permeable/well-drained areas of land (Doherty *et al*. 2007, 2008). Furthermore, (some) water is naturally released through a sinkhole near the southern rim of the plain that channels water

into the Mediterranean via the Taurus underground network, while other sinkholes (e.g. Timsa near Çumra) and depressions in the surface direct water northwards to the basin of Tüz Gölu (Erol 1991; Kuzucuoğlu *et al*. 1998); also, inflow of the rivers collects, where possible, at the basin's lowest spots (Driessen 1970: 11). A study of water tables from 500 locations across the plain was carried out in spring (May) and autumn (September) of 1967, and it showed that the 'agriculturally important' top soils, down to 2 m depth, are relatively dry and significantly drier in autumn than in spring (Driessen 1970: 11, Fig. 9).

The hydrology of the Konya basin has been considerably influenced by recent water management - e.g. construction of dams, and an extensive network of irrigation and drainage canals over much of the alluvial deposits near Çumra (Driessen 1970; Rosen and Roberts 2005) and the current picture may not be relevant to the past (Roberts 1983). At present the Çarşamba is canalized several kilometres south of Çumra (Driessen and de Meester 1969; Doherty and Camizuli 2008). Prior to the introduction (from the 1950s onwards) of the system of river regulation and irrigation, the main activity on the plain was herding, but some arable farming was also practised (Hütteroth 1968: 61; Kuzucuoğlu *et al*. 1998). Sheep grazing was associated with seasonal nomadism; extended families stayed in villages during the summer and moved to towns for the winter (Kuzucuoğlu *et al*. 1998). Sheep flocks used to be brought from distant southern slopes of the Taurus to graze in the interior of the Plateau. Animal husbandry also included goats, camels and horses. Permanent villages existed along the Çarşamba river even before the establishment of irrigation canals and water distribution mechanisms, which included widening and lengthening of 'old Çarşamba arms', suggesting that water availability/irrigation was adequate for agriculture; indeed, the old Çarşamba channels were used for small-scale irrigation of arable fields (Hütteroth 1968: 61). Nowadays, animal husbandry is in decline as more and more land is used for irrigated farming - mostly cultivation of cereals and sugar beets (Kuzucuoğlu *et al*. 1998). Water from several reservoirs and natural lakes (e.g. Beyşehir), as well as groundwater, is pumped up and used to irrigate fields in the plain (Driessen 1970; Rosen and Roberts 2005). However, poorly designed irrigation systems (with no adequate drainage) resulted in high salinity (salt content) and alkalinity (sodium content) of the soil, which have drastically reduced the crop yields, threatening the overall agricultural production in the basin (Driessen 1970; Hamzaoğlu and Aksoy 2009).

2.3.1.3 **Vegetation**

Climatically and floristically, Central Anatolia belongs to the Irano-Anatolian province of the Irano-Turanian region, which also includes Turkish Mesopotamia, much of the Syrian Desert, Inner Anatolia (Central and East), most of Iran and Afghanistan, and some parts of Middle and Central Asia (e.g. Turkmenistan, Uzbekistan and further to the east, Mongolia and Tibet) (Zohary 1973: 88). Although vast, the whole territory is characterised by a continental climate, with extreme ranges in temperature, low precipitation, and two seasons of dormancy in plant growth - cold harsh winters and very hot summers (Zohary 1973: 87). The Irano-Turanian region is the largest of the three in Turkey (the other two being the Mediterranean and Euro-Siberian) and has two major vegetation zones, excluding high-altitude flora: a wide area of deciduous scrub and park-like forest along the periphery, and treeless ('true') steppe in the inner area, of which the most extensive is the Central Anatolian steppe encompassing the Konya plain (Davis *et al*. 1965).

As mentioned above, a striking feature of the Konya plain is very low humidity (e.g. much lower than in the Mediterranean), which favours herbaceous and suffruticose flora and hinders the growth of evergreen (conifer) trees and shrubs. Due to the soaring summer temperatures vegetation on the plain usually becomes desiccated over the summer, especially after the flowering stage (Davis *et al*. 1965). The predominant vegetation is treeless steppe, where *Artemisia fragrans* and *A. spicata* are leading species, accompanied by several species of *Stipa* and *Astragalus*, as well as taxa such as *Euphorbia tinctoria, Linum hirsutum, Phlomis armeniaca, Poa bulbosa, Teucrium orientale.* Halophytic (salt-loving) vegetation occurs around salt lakes and in saline places and is represented by many species of *Chenopodiaceae*. Reeds, rushes and sedges are common in marshlands and nearby lakes and rivers; riparian vegetation along river courses also includes willow, poplar and elm. Mountain slopes and terraces are now barren and usually covered with 'mountain steppe', where *Bromus tomentellus* is relatively widespread, while spiny cushion plants *(Astragalus*, *Onobrychis*) increase with altitude. Trees and scrub are restricted to the upland zone except for the northern slopes of Karacadağ and Karadağ still covered by woodland steppe or park (open) woodland, where for example fir, juniper, deciduous oak, hackberry, hawthorn, wild almond and other rosaceous trees and scrubs can still be found. They represent relics of the previously extensive open oak woodlands now reduced by woodcutting, felling and browsing. True upland vegetation consists primarily of coniferous forests with pine, cedar

and fir trees. Juniper, oak and hackberry trees sometimes occur in lower altitudes, e.g. along edges of the Anatolian steppe and at the foot of the mountains, as part of woodland steppe vegetation (Davis *et al*. 1965-1988; Zohary 1973; Hillman 2000a; Asouti and Hather 2001; Kuzucuoğlu 2002; Asouti 2005b).

2.3.2 **Early Holocene environment of Central Anatolia and the Konya plain**

A general warming trend marks the onset of the Holocene in the eastern Mediterranean region. Following the high aridity and cold conditions of the Younger Dryas, reflected in open steppe vegetation composed mainly of *Artemisia*, *Chenopodiaceae* and *Compositae*, the expansion of oak at the end of the Younger Dryas (about 10,500 BP) indicates good moisture conditions, and that of terebinth (pistachio) suggests higher temperatures (Rossignol-Strick 1995; Wick *et al*. 2003). The Anatolian peninsula experienced more humid conditions between *c*. 8600 BC and 6900 BC (10,600 – 8900 BP) both in comparison to the present day situation and to the climate conditions of the Late Glacial (Roberts *et al*. 2001; Eastwood *et al*. 2007).



Figure 2.6 The mentioned locations in Central Anatolia with studied palaeoclimatic sequence

(Map background - Sherratt, A. and F. Menotti 2006 *ArchAtlas* at http://www.archatlas.dept.shef.ac.uk/SitesFromSatellites/sites.php?name=catalhoyuk)

The available reconstructions of past climatic conditions in Central Anatolia draw upon pollen, ostracod, diatom and isotope evidence from the Eski Acigöl lake in Cappadocia, palaeohydrology of Lake Konya (and Lake Van further to the east), study of aeolian landforms (sand dunes) in the Konya plain, pollen data from lakes Akgöl Adabağ in the Konya basin and Beyşehir in the Lake District, pollen data from the Melendiz river, and chemical properties of lacustrine sediments, combined with radiocarbon and OSL (optically stimulated luminescence) dates from the region (Roberts 1983; Bottema and Woldring 1984; Lemke and Sturm 1997; Woldring 1998; Kuzucuoğlu *et al*. 1998; Roberts *et al*. 2001; M. Jones *et al*. 2007; Turner *et al*. 2010). Although the available information on climate of the region does not specify conditions in the immediate area around Çatalhöyük (Fig. 2.6), the available data from adjacent locations fit the general picture of increased precipitation and resulting environmental changes in the Early Holocene in the eastern and central Mediterranean and beyond, e.g. in the Saharo-Arabian zone (Fontugne *et al*. 1999; Roberts *et al*. 1999, 2001; M. Jones *et al*. 2007).

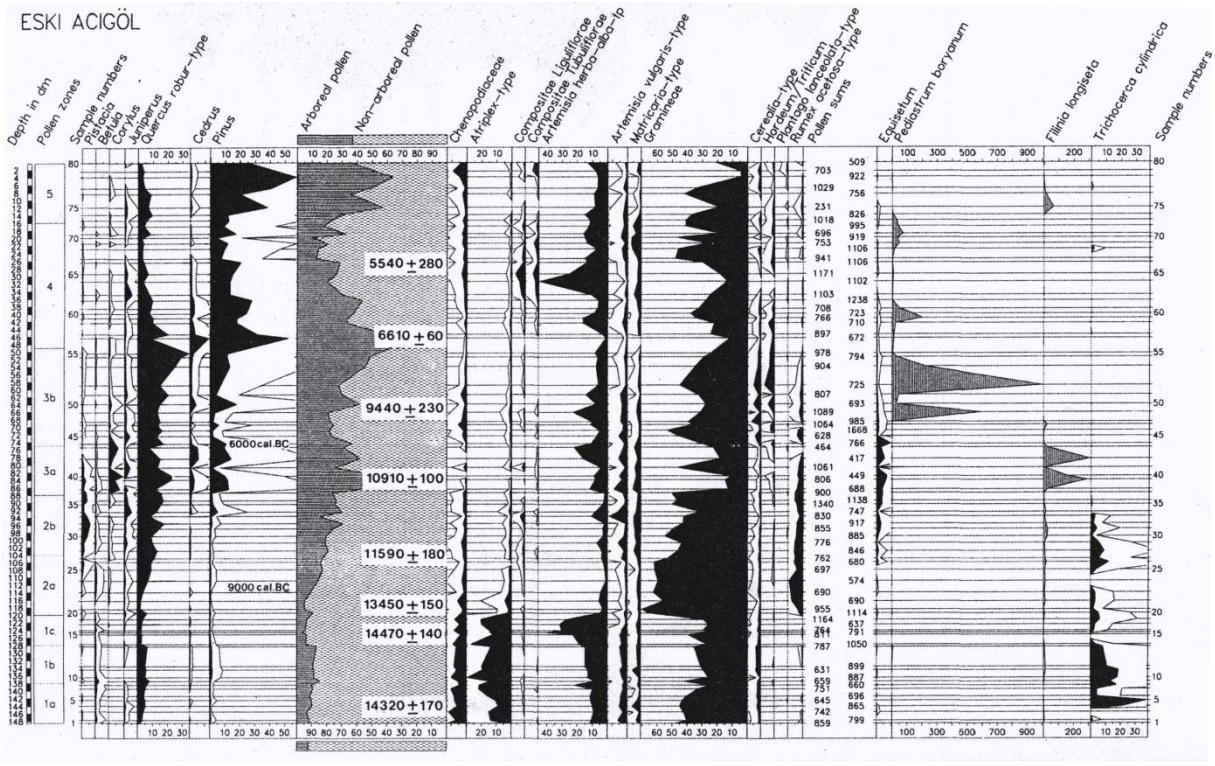


Figure 2.7a Summary pollen diagram from Eski Acigöl (ESK92 core) (after Roberts *et al*. 2001: Fig. 6)

2.3.2.1 **Climate and vegetation**

A rapid rise in humidity in the Early Holocene (at around 12,000 BP) is noted in the multi-proxy record (pollen, isotope, diatom etc) from Eski Acigöl in Cappadocia, some 200 km to the northeast from Çatalhöyük (Fig. 2.7a-b). This caused abrupt changes in the vegetation cover: Late Pleistocene arid steppe (*Artemisia* - *Chenopodiaceae*) gave way to grassland (e.g. *Stipa, Bromus, Festuca*), and arboreal taxa (such as birch, oak, terebinth and juniper) were on the steep increase (Roberts *et al*. 2001; Woldring 2002).

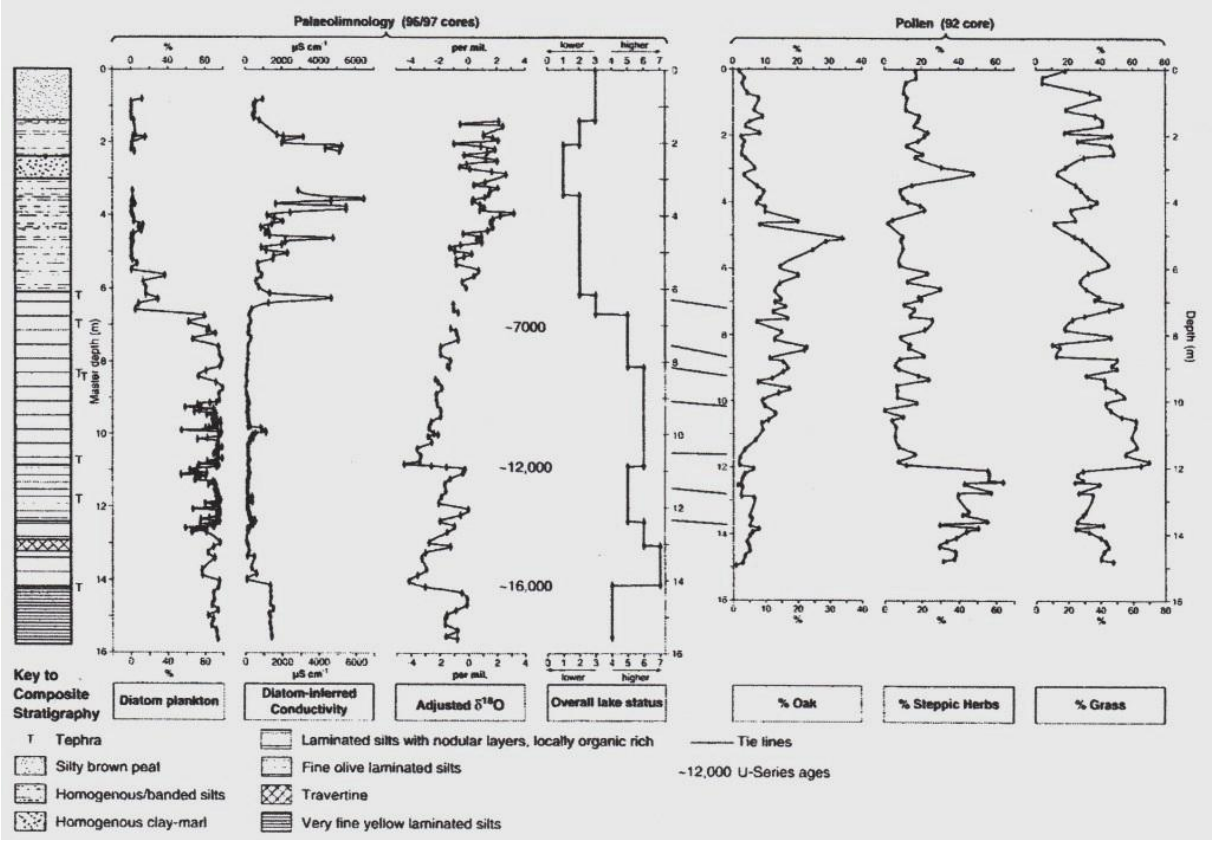


Figure 2.7b Correlation between the results from the palaeolimnological and palynological analysis (ESK92 core) at Eski Acigöl indicating environmental changes of the Late Pleistocene - Early Holocene transition (after Roberts *et al*. 2001: Fig. 7)

The Late Glacial-Early Holocene pollen evidence from the Akgöl Lake in the Ereğli marshes at the eastern end of the Konya basin, *c*. 85 km from Çatalhöyük (Fig. 2.8), however, shows a more gradual increase in deciduous oak and conifer forest and some other deciduous taxa, as well as slow but steady development of grass-steppe and the decrease of desert-steppe taxa (e.g. *Artemisia*) (Bottema and Woldring 1984: 133). The Akgöl record has therefore been understood as indicating still dry climate at the onset of the Holocene in the Konya plain,

with only slow/gradual advance of wet conditions, and the changes in vegetation 'lagging' behind those in other regions of Central Anatolia (Kuzucuoğlu 2002; Roberts *et al*. 2007). Although the sediments of the Çarşamba fan show that alluvial deposition started at the beginning of the Holocene (Roberts *et al*. 1999; see below), suggesting higher water availability/precipitation, the levels of wetland taxa in the Akgöl pollen core were seen as too low to suggest formation of marshes or lakes as a result of the increased moisture (Kuzucuoğlu 2002). Similarly, a pollen diagram from the Melendiz river nearby Aşıklı Höyük, with minimum radiocarbon-dated age of 7952 BC, shows an abundance of non-arboreal taxa (e.g. *Chenopodiaceae, Composiate*), and a small amount of arboreal taxa such as oak, juniper, birch and pine, probably deriving from the surrounding mountains; the record, however, covers only a short phase of the Early Holocene history and is representative of a very restricted area (Woldring 1998).

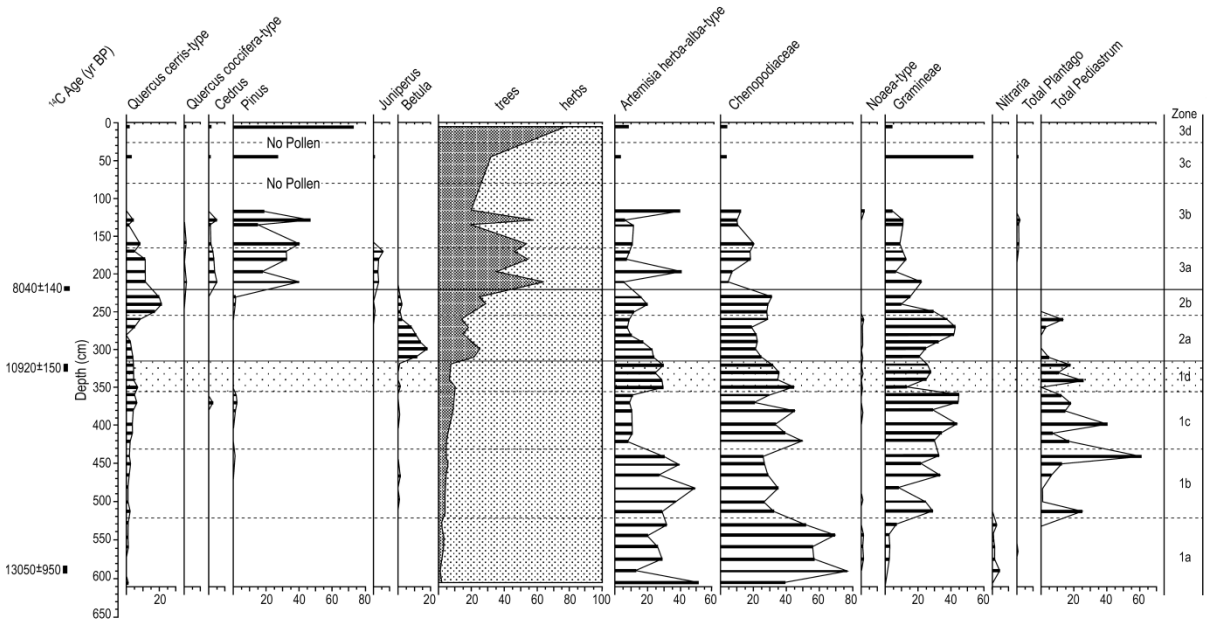


Figure 2.8 Summary pollen diagram from Akgöl Adabağ (after Woldring 2002: Fig. 2; reproduced from Roberts *et al*. 2007: Fig. 4.13)

On the other hand, the Early Holocene Akgöl record *does* detect an overall increase in the pollen levels of arboreal, wetland and grassland taxa, suggesting relatively high climatic moisture - i.e. higher annual precipitation compared to the Late Pleistocene and Late Holocene levels - and perhaps shorter period/limited effect of summer drought (Bottema and Woldring 1984; Woldring 2002). This development represents a unique phase in the environmental history of Central Anatolia, as it diverges from both semi-desert treeless steppe landscape of the Late Pleistocene, and the Mid-Late Holocene (post-8000 BP) dry

conditions (Bottema and Woldring 1984; Woldring 2002; Woldring and Bottema 2003; Roberts *et al*. 2001, 2011). Moreover, it was the (single) period of the Holocene when, based on the moisture levels, rain-fed crop cultivation would have been possible in the Konya plain (Charles *et al*. in press/2013).

The Akgöl pollen evidence points to existence of deciduous woodland in the uplands surrounding the plain, dominated by oak and including taxa such as elm, maple, hazel and, most probably, many other taxa that are insect-pollinated (e.g. almond and *Prunus*) and remain invisible in pollen diagrams (Bottema and Woldring 1984; Woldring 2002; Asouti in Kuzucuoğlu 2002: 47; Asouti 2005b). Tree-taxa such as *Celtis* (hackberry), almond and terebinth, characteristic of woodland steppe, could also grow in drier areas in the lowlands, otherwise occupied by grasses and marsh/riverine vegetation (Asouti 2005b, in press/2013). The Akgöl evidence suggests a further increase in humidity up to 8000 BP, based on the increase in arboreal pollen levels, particularly the values for pine which, compared to oak, has lower drought tolerance; pine was accompanied by cedar and juniper. Wet-loving taxa also become more frequent in this period, e.g. *Sparganium*, *Equisetum*, *Nymphea* (Bottema and Woldring 1984).

The available palaeoenvironmental record from Central Anatolia demonstrates that, by the appearance of the first known Neolithic settlements in the region (*c*. 10,000 BP; Boncuklu Höyük in the 9th millennium BC), the harsh climate of the Late Glacial had improved to warm and wet Early Holocene conditions. The pollen sequences show increases in woodland (oak-terebinth) and grassland taxa, and indicate region-wide transformation of the former vegetation cover. These developments coincide with, and represent the environmental context of, the emergence of the Central Anatolian Neolithic (the ECA II phase); for instance, the zone 2a-2b transition in Eski Acigöl pollen sequence (Fig. 2.7a) is considered contemporary with Aşıklı Höyük occupation (Woldring 2002). By the time of the main (ceramic) Neolithic occupation at Çatalhöyük East, the arid steppe landscape of the Late Glacial had long been replaced by a mosaic of woodland and open grassland (Asouti 2005a).

2.3.2.2 **Soils of the Çarşamba alluvial fan**

The results of geomorphological investigations, as part of a broader regional study (the KOPAL survey - Roberts *et al.* 1999, 2007; Boyer *et al.* 2006) at Çatalhöyük demonstrated

that the site was founded on the Çarşamba alluvial fan, on the eastern (right) bank of the river; a buried river palaeo-channel dated to *c.* 6600 BP was identified *c.* 0.5 km south of the site (Boyer *et al*. 2006; Roberts and Rosen 2009). The sequence and extent of alluviation, at least for the zone around Çatalhöyük, has been suggested based on the findings of coring of the sediments carried out around the site and on its edges. The off-site sediment stratigraphy shows presence of: a) 'thin (*c.* 20 cm) dark organic clay overlying the basal [lacustrine] marl', possibly a marsh deposit forming in shallow depressions, b) a *c.* 1.5 m layer of dark grey-brown clay with high organic content, termed Lower Alluvium, and c) a layer of *c.* 1.3 m reddish-brown silt-clay with lower organic content, termed Upper Alluvium (Boyer *et al*. 2006). Active alluviation by the Çarşamba began in the Early Holocene and the Lower Alluvium represents the first Holocene accumulation; the base of it was dated to 9500 cal. BP, just before the start of occupation at Çatalhöyük, and it continued throughout the Neolithic (Boyer *et al*. 2006). A localised hiatus in sedimentation (noted in KOPAL 99 trench sequence) between the Neolithic and the Early Chalcolithic was observed above the Lower Alluvium where a buried soil horizon was identified and dated to 8000 cal. BP (Boyer *et al*. 2006; Roberts *et al*. 2007). Dating of the base of the Upper Alluvium shows that its deposition commenced around 4200 cal. BP, continuing into at least the first millennium AD (Boyer *et al*. 2006). Therefore, the sequence of the Holocene alluvium deposition 'events', resulting from standing flood waters, appears to be relatively straightforward for this part of the Çarşamba fan; the fine-grained heavy backswamp clay of the Lower Alluvium in-filled depressions in the terrain remaining from the Pleistocene and covered and levelled the marl surface, giving the shape and defining edges of the Çarşamba fan. The 'delayed' deposition of lighter-coloured somewhat coarser Upper Alluvium, and over a smaller, central area of the fan, perhaps shows changes in the flooding regime and/or sources of sediment (Brown 1997; Boyer *et al*. 2006). The distribution of the Lower Alluvium broadly relates to the formerly recorded area of backswamp deposits (Driessen and de Meester 1969; Boyer *et al*. 2006).

According to the KOPAL view, fine-grained clay-rich alluvium was deposited in the vicinity of the settlement, in a radius of *c.* 10 km around the site (Fig. 2.9). The alluviation continued throughout the site's occupation and, due to the to the annual flooding of the Çarşamba and the lack of natural water outflow, much of the area around the site was inundated throughout spring, while some parts stayed wet for longer periods resulting in slow evaporation and salinisation. As a result, the Çarşamba fan resembled temperate floodplains, where wetlands and marshes dominate the landscape (Driessen and de Meester 1969; Roberts *et al*. 1996,

1999, 2007; Roberts and Rosen 2005). In backswamp environments plant diversity and growth are determined by the lack of oxygen due to waterlogging, and lack of nitrogen due to the slow rate of decomposition of organic matter (Brown 1997: 112). These conditions are favourable mainly for monocotyledons (rushes, sedges and grasses) and tree species that can fix nitrogen directly from the air, such as alders (Brown 1997: 112). The archaeobotanically identified flora of Çatalhöyük, however, is extremely diverse and originates from a range of dry and wet habitats (see below).

New geomorphological work initiated in the summer of 2007 (the Landscape and Coring Programme), combined with clay sourcing and provenance research and mudbrick micromorphology has pointed to multiple problems concerning the proposed palaeoevironmental reconstruction (Doherty 2007, in press/2013; Doherty *et al*. 2007, 2008; Doherty and Camizuli 2008; Love 2012; also Matthews *et al*. 1996; Matthews 2005a; Tung 2005).

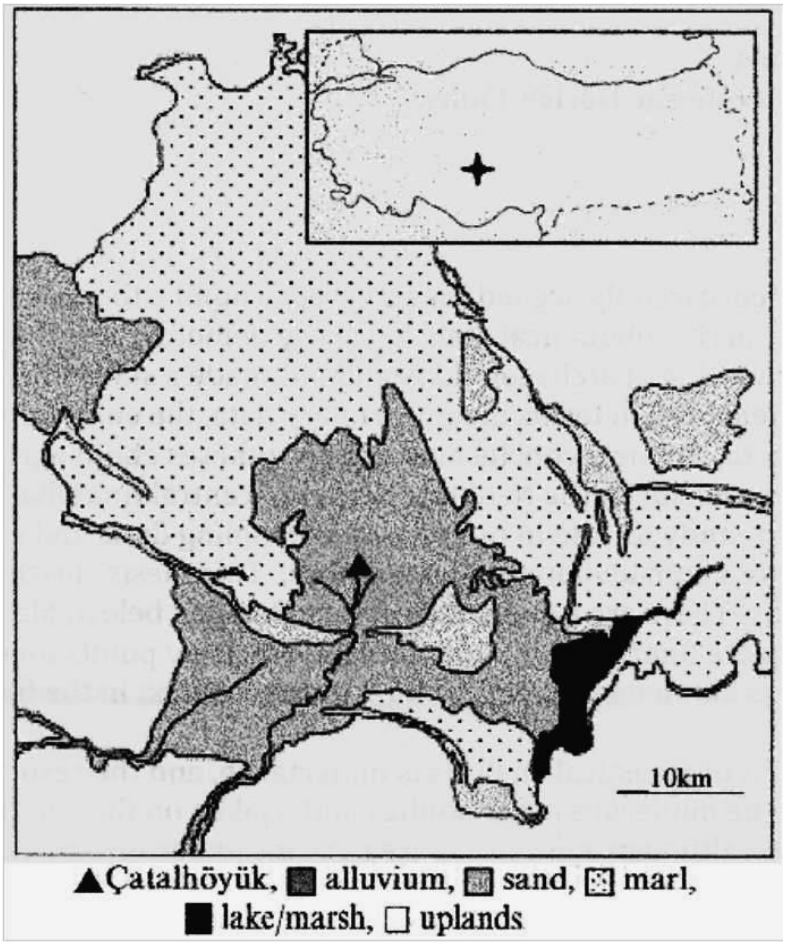


Figure 2.9 Soil types and landforms around Çatalhöyük
(after Roberts *et al*. 1996; reproduced from Fairbairn 2005: Fig. 1)

Most of the uncertainties relate to the somewhat simplified picture of the soil distribution in the Çarşamba fan (and beyond) which does not take into account the potential variation and discontinuity in soil distribution across such a large area (cf. Brown 1997). For example, the duration of the Lower Alluvium 'phase' is ambiguous; while absent at Çatalhöyük over the several-millennia long hiatus (as observed in a single coring location), the Lower Alluvium continues to be deposited at other locations on the fan until much later periods, e.g. at Late Chalcolithic Avrathanı and Early Bronze Age Kızıl (Boyer *et al*. 2006: 685; Doherty in press/2013). New coring sequences suggest that the impermeable Pleistocene lake marl was discontinuous in its distribution and interbedded with Pleistocene sands, silts and clays near the edge of the former lake, allowing for run-off of surface water through these sediments (de Ridder 1965; Doherty *et al*. 2007). Further supporting evidence for greater diversity of sediments comes from micromorphological analysis of the mudbrick which discovered that, instead of dark silty clay from alluvial backswamps, oxidized orange or brown silty and sandy loam sediments were used for making mudbrick from Level VII/South M onwards (Matthews 2005a; Tung 2005). These sediments also occasionally appear, in the form of aggregates, in earlier levels of the site (e.g. Level IX/South K) (Matthews 2005a), but were not present/recognised in the geomorphological samples. Furthermore, analysis of clay sourced for mudbrick production has shown that the majority of mudbricks used after Level VIII-VII/South L-M was made of material corresponding to Upper Alluvium which, at least at Çatalhöyük, occurs much later than this (Doherty 2007). Also, the KOPAL sediment study did not detect presence of levees (Boyer *et al.* 2006), which normally occur along the potentially meandering/channel-shifting nature of the Çarşamba river (at least through this part of the Konya basin), as suggested by the extensive backswamp deposits resulting from seasonal flooding (Baird 2005; Doherty in press/2013). Spring floods cause breaking of the channel banks, after which they lose in speed and start gradual deposition of their sediments; coarse materials stay near the channel edges and build up to form levees which tend to be sandy and relatively free-draining (Brown 1997: 111; Doherty in press/2013).

Clearly, the understanding of microtopography and potential for drainage of Çatalhöyük's environs is critical for reconstructions of the physical landscape of the settlement and its potential for providing subsistence basis (Charles *et al*. in press/2013). The recent geomorphological results, combined with archaeological (e.g. mudbrick) and environmental evidence, bring into question the previously proposed palaeoenvironmental model for

Çatalhöyük and, *inter alia*, suggest much more favourable conditions for arable production than initially put forward.

2.3.2.3 Çatalhöyük vegetation reconstruction - archaeobotanical and wood charcoal record

The distance from Çatalhöyük to Akgöl and other sites yielding pollen data, and in some cases the low level of chronological detail of the sequences (e.g. lack of data in the Akgöl record corresponding to the earliest occupation at Çatalhöyük) impede high-resolution reconstructions from the pollen spectra of the environment and environmental change around the settlement. Moreover, some important tree taxa are either insect-pollinated (such as *Acer*, *Amygdalus*, *Celtis*, *Prunus*) or low pollen producers (e.g. *Pistacia*, *Juniperus*) and are therefore palynologically underrepresented (Roberts *et al*. 2001; Asouti 2005b). The Çatalhöyük charcoal record provides a solid basis for the reconstruction of the composition and distribution of vegetation formations in the Konya plain in the Neolithic (Asouti and Hather 2001; Asouti and Fairbairn 2002; Asouti 2003, 2005b). Although the range of tree-taxa found in archaeological layers is culturally determined, being shaped through the selection of wood for fire and timber, the charcoal data, supported by the off-site palaeoenvironmental evidence (e.g. Bottema and Woldring 1984; Fontugne *et al*. 1999; Roberts *et al*. 2001), research on soil types and their modern distribution (Driessen and de Meester 1969; de Meester 1970), and the available modern floristic and ecological studies of vegetation in south-west Asia (Davis *et al*. 1965-1988; Zohary 1973; Hillman 2000a), offer valuable evidence in support of the pattern of Early Holocene environmental change documented in the pollen sequences (Asouti and Hather 2001, Asouti 2005b).

Wetland trees and shrubs in the charcoal assemblage document the presence of riparian and marsh vegetation in the (immediate) surroundings of the settlement. The periodically inundated surfaces were occupied by grasses, reeds and rushes. In less wet areas (e.g. levees) riverine forest taxa such as willow/poplar and elm were common, whereas woodland stands in permanently/seasonally submerged areas near the site (marshes, shallow pools) were dominated by taxa such as alder and salt-tolerant tamarisk. In the dry open areas of the Konya plain, there existed three dominant vegetation types: a) steppe/grassland on the margins of the Çarşamba fan and beyond the zone intermittently exposed to flooding (‘marl steppe’), often interspersed with perennial (sometimes salt-tolerant) shrubs of, for example, families

Chenopodiaceae, *Compositae*, *Labiateae*; b) woodland steppe, including species such as hackberries, terebinth, and almond, growing on rocky outcrops and colluvial hillslopes outside the alluvial plain, but also on sandy and clayey soils within the plain as long as they are well-drained surfaces with low water table and low evaporation rates; c) open (park) oak woodland in the uplands surrounding the Konya plain, especially towards the southern edges where major taxa included deciduous oaks, wild pears and plums, hawthorns, almonds, hackberries, terebinths, junipers, woody legumes and rose bushes (Asouti and Hather 2001; Asouti and Fairbairn 2002; Asouti 2003, 2005b).

The rich and diverse archaeobotanically identified flora at Çatalhöyük (Fairbairn *et al*. 2002, 2005a) can be accommodated within the generalised model of vegetation distribution for the Konya plain. The potential origin of the taxa points to the presence of a series of environmental gradients around the site, from low lying wetlands to dry uplands (Fairbairn *et al*. 2005a: Table 8.3). Riparian and marsh flora included herbaceous taxa such as *Bolboschoenus glaucus* (previously identified as *B. maritimus*; Wollstonecroft *et al*. 2011), *Eleocharis, Carex, Aeluropus* and highly ubiquitous *Phragmites* (reed). A few aquatic taxa derive from ponds or flooded shallow depressions (e.g. *Potamogeton, Alismataceae*). Several salt-tolerant taxa were discovered - *Suaeda, Beta, Atriplex, Salsola*. A number of taxa of potential steppe origin were identified, including *Camphorosma, Artemisia, Eremopyrum* and *Stipa*. A large number of taxa can grow in naturally or anthropogenically disturbed environmental conditions, for example *Taeniatherum caput-medusae*, *Helianthemum*, *Astragalus/Trigonella*, *Phlomis*; some arable/ruderal taxa were present as well - *Vaccaria pyramidata, Buglossoides arvensis* etc and probably *Heliotropium, Centaurea, Polygonum, Phalaris*. Definite arable weeds could not be specified due to the mixing of plant material from different activities/processes (e.g. crop processing and burning of dung). Tree and shrub taxa come from park woodland covering ridges and hills, and in places perhaps overlapping with the steppe zone, e.g. *Pistacia, Quercus, Amygdalus, Prunus* (Fairbairn *et al*. 2002, 2005a).

A range of vegetation formations is suggested by the presence of taxa with different ecological requirements and tolerances (Fig. 2.10). The majority of the identified taxa occupy dry land, suggesting that, even if the landscape was mostly wet, there were numerous dry locations, such as marl rises, sand ridges, levees and dry steppe, with hills beyond. The presence of such a diverse flora demonstrates use of a varied landscape, both the resources in

the immediate vicinity to the site and those that were perhaps located at some distance from the site (i.e. juniper stands in the uplands) (Asouti 2005b; Fairbairn *et al*. 2005a).

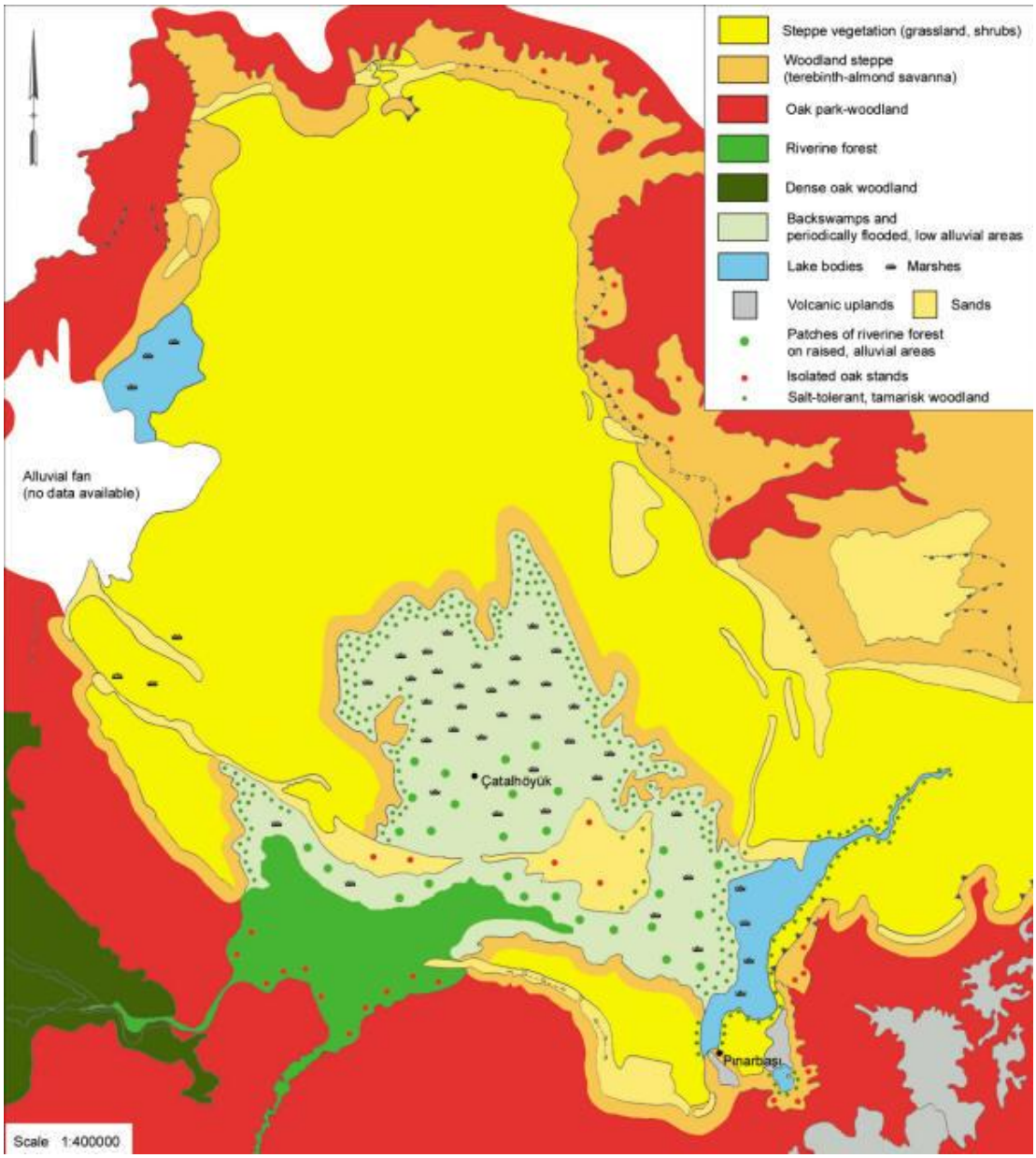


Figure 2.10 Reconstruction of the different Neolithic vegetation formations in the Konya plain based on the charcoal evidence from Çatalhöyük and Pınarbaşı A, the palaeoenvironmental analysis, and data on the modern soil and vegetation distribution in the region (after Asouti 2005b: Fig. 10.20)

The charcoal record from the earliest levels of Çatalhöyük (Asouti and Hather 2001; Asouti 2005b) does not support the earlier impression from the pollen data, that the overall radical change from dry to wet climate at the onset of the Holocene in Anatolia and beyond was delayed and/or prolonged in the Konya plain (Kuzucuoğlu 2002). The presence of arboreal

(oak-terebinth-juniper) and non-arboreal (e.g. grassland) vegetation in Çatalhöyük's surrounding is apparent from the early stages of the habitation, suggesting woodland expansion and availability of these resources from the beginning. It further implies higher precipitation than at present and overall water availability favourable for the growth of oak woodland on lower hill slopes (Asouti 2005b: 251). As suggested by the charcoal evidence from Çatalhöyük and Pınarbaşı A, advancement of woodland steppe vegetation during the Early Holocene in Central Anatolia was also possible, and it would have occupied edges of oak park woodland in the mountain zone (the foothills) or well-drained parts of the plain (Fairbairn *et al*. 2002; Asouti 2003, 2005b).

2.3.2.4 **Environment and agriculture at Çatalhöyük**

In the warm and moist Early Holocene Konya basin, the increased activity of numerous streams and springs in the area developed alluvial deposits with high potential for cultivation (Baird 2002, 2005); however, the closed hydrology and poor drainage of the basin resulted in increased surface and groundwater levels and development of features such as marshes and minor lakes above the Pleistocene lake sediments across the plain (de Ridder 1965; Kuzucuoğlu 2002; Boyer *et al*. 2006). Reconstruction of the Çatalhöyük environment based on the geomorphological survey offers a picture of a low-lying floodplain composed of wet backswamp areas in both the immediate environs of the site and the wider area (Roberts *et al*. 1996, 1999; Boyer *et al*. 2006). The implication is that the mostly flat area surrounding the site for some kilometres was not suitable for reliable crop cultivation and that, based on the present-day distribution of higher ground, distances to dry land supporting potential cultivated plots would have exceeded 10 km (Rosen and Roberts 2005, Roberts and Rosen 2009). The results of the KOPAL study were interpreted as suggesting that the choice of site location was made primarily (or solely) on the basis of the diversity and availability of wild plant and animal resources, and not with a view to arable cultivation (Hodder 2005; Rosen and Roberts 2005; Roberts and Rosen 2009).

The proposed conditions would not have been adequate for woodland species, as fine-grained alluvium with high clay content retains ground moisture close to the surface, which is convenient for herbs and grasses, especially annuals well adapted to high water table, but not for trees with deep-penetrating roots and requiring water availability in lower levels (Asouti 2005b). Away from the alluvial plain, marl steppe extending over the greater part of the

Konya plain is also not a favourable environment for trees due to the inhibited root development and soil aeration (Zohary 1973; Hillman 2000a; Asouti 2005b). Therefore, areas that could have supported woodland steppe or park (open oak) woodland are probably the same raised areas visible today - the sand ridges *c*. 7 km southwards from the site and, beyond them, hill zone and dry steppe zone at the foothills of the mountains 13 km to the south; volcanic slopes some 7 km to the north are another possible location, a setting similar to woodland steppe noted at the foothills of Karadağ (Hillman 2000a; Asouti and Fairbairn 2002; Fairbairn *et al*. 2002; Asouti 2005b).

From the variability in elevations of the lake marl underlying the alluvium (Boyer 1999) it is apparent, however, that the topography of the former lake bed was uneven and interspersed with marl hummocks and sand ridges, and that the river action distributed alluvial sediment irregularly over the plain, creating levees (Baird 2002, 2005; Fairbairn *et al*. 2005a). Major spring flooding would have deposited alluvium on top of the raised areas, which would in turn have represented potential agricultural land (Asouti and Hather 2001, Fairbairn *et al*. 2005a; Fairbairn 2005; Baird 2005). Moreover, the rate of alluviation across the Çarşamba fan would have been temporally and spatially variable depending on the frequency and extent of flooding; the river channel(s) may have not been stable and may have shifted horizontally, affecting the distribution of levees (Baird 2002: 141, 2005; Boyer *et al*. 2006: 685; Charles *et al*. in press/2013). Also, the Çarşamba is a karstic river and loses much of the water through cavities in the limestone hills to the south in which its valley is incised (de Ridder 1965: 233). Although the exact distribution in the Neolithic of the identified vegetation types remains uncertain, especially for taxa such as steppic trees and shrubs, based on the observations of modern ecological distribution in south-west Asia (Zohary 1973; Hillman 2000a) the occurrence of tree taxa (typical of woodland steppe and park woodland) in the alluvial zone would have been possible; this would indicate the existence of well-drained, coarse-textured soils (with low water table) closer to the site, such as generally dry sand/clay ridges and levees which could sustain oak stands (Asouti 2005b). The prevailing climate during the Neolithic occupation of Çatalhöyük appears to have been moister than today and favourable of woodland expansion (see above), meaning that the dry-season shortage in soil moisture affecting vegetation would not have been as severe as today (Fontugne *et al*. 1999; Asouti and Hather 2001); this raises the plausibility of the Early Holocene rain-fed farming in the Konya basin.

The location of Çatalhöyük on an alluvial fan (similar to other Neolithic sites in the Konya plain, such as Canhasan III on the alluvial plain of the Selereki river - French *et al*. 1972) within the internal drainage system of the Konya basin recalls the geographic setting of early farming settlements in the Levantine corridor from an earlier stage of the development of farming in south-west Asia. Sites such as Jericho (e.g. Kenyon 1985) and Netiv Hagdud (Bar-Yosef and Gopher 1997) in the Jordan valley, and Tell Ramad and Tell Aswad (de Contenson 1971; de Contenson *et al*. 1995, 2000) in the Damascus basin are all situated in the areas where watercourses flowing from the hills enter open country (valleys) creating alluvial fans, and springs sporadically emerge at head of these fans (Sherratt 1980, 2005, 2007). Sherratt (1980, 2007; see also Vita-Finzi 1969) argued that the seasonally wet fine-grained alluvium in the vicinity of the Levantine sites offered highly productive agricultural land, attractive to early farmers for cultivation as well as for abundant wild plant and animal sources.

Sherratt (1980, 2004) also saw the selective geographical distribution of early farming settlements in the Levant as a pattern visible in other areas of the Near East in later stages of the spread of a new (agricultural) mode of subsistence (e.g. to the middle Euphrates, south-east Turkey, south-west Anatolia) and, in succeeding phases, to southern and central Europe. He proposed the 'floodwater farming' model of crop cultivation for these early agricultural settlements (Sherratt 1980), characterized by small-scale locally focused exploitation of nutrient-rich, well-watered alluvial fan soils. Due to seasonal flooding, crops would have been sown in early spring, to 'take advantage of the short period of optimum water-availability between winter floods and summer desiccation, allowing the three months' growing in spring (March-May) which is necessary for a crop' (Sherratt 1980: 317). In terms of labour-inputs, cultivation of these soils would not have been intensive and would not require much soil preparation (forest clearance, hoeing etc) or field maintenance (weeding etc) (Sherratt 1980: 318). It was argued that this simple agricultural technology could explain the logic behind the choice of location of early farming settlements in the Levant and beyond, as it was the most suitable method of cultivation on widely available rich low-lying soils with high groundwater or those left exposed by spring floodwaters.

Archaeobotanical investigations have confirmed the use of alluvial soils for cropping in the initial stage of cultivation in parts of south-west Asia (Colledge 1998, 2001: 191); agricultural practices have not been explored in detail, mainly due to the uncertain taphonomic impact on archaeobotanical assemblages of burnt animal dung used as fuel (e.g.

Miller and Smart 1984; Charles 1998). Direct evidence for the nature of crop husbandry and crop growing conditions is provided by the seeds of arable weeds that grew and were harvested with crops (Charles *et al*. 1997; Jones *et al*. 1999, 2000a; Jones 2002; Bogaard 2004a); however, at Çatalhöyük clear separation between weed and dung-derived taxa was not possible and so crop field conditions and husbandry practices were difficult to reconstruct (Fairbairn *et al*. 2002, 2005a; Fairbairn 2005).

Autumn sowing of cereals on dry land has been suggested on the basis of arable weeds found in crop stores (Fairbairn *et al*. 2005a; Fairbairn 2005). Wild and domesticated cereal species of the Near East are genetically adapted to a long, nine-month growing season - they have strong vernalisation (exposure to cold/winter conditions) requirement prior to flowering and seed-setting (Willcox 1992; Fuller and Allaby 2009). Vernalisation is often combined with photoperiodism - a requirement for a certain day length before flowering commences; in some taxa a particular day length is essential for flowering, while in others a particular day length accelerates, but is not essential for flowering (Thomas 1993; Thomas *et al*. 2006: 4). There are also taxa that flower at the same time irrespective of the photoperiodic conditions ('day-neutral plants' - Thomas *et al*. 2006). The response to variations in day length enables plant taxa to adapt to seasonal changes in their environment, and can be detected in genetic pathways that control the flowering time (Thomas 1993; Thomas *et al*. 2006). A recent genetic study of the photoperiodicity in wild and domesticated barley landraces from the Fertile Crescent and Europe has revealed the presence of the photoperiod nonresponsive haplotypes in the two groups (H. Jones *et al*. 2008). Barley plants with the nonresponsive phenotypes are not sensitive to day length and have constant flowering time under long or short day conditions. This means that there was no genetic adaptation/mutation in domesticated barley that would involve the change in flowering time as a result of potential interference with the seasonality of the growth cycle (e.g. spring sowing) and/or dissimilarity in environmental conditions between south-west Asia and Europe. The study also indicates a straightforward link between the wild and cultivated barley populations, whereby the nonresponsive haplotypes accessed the cultivated gene pool directly from the wild before or during the spread of farming into Europe, where this genetic pathway was retained (H. Jones *et al*. 2008). Moreover, the responsive type barley appears to be a late introduction into northern Europe, derived from domestication of a responsive wild type in the eastern Fertile Crescent. Based on this, it is highly unlikely that a shorter ('accelerated') growth period of

barley (and perhaps other cereals) as a consequence of spring sowing would have been developed in the early Holocene (cf. Hillman and Davis 1992; Sherratt 2007: 8).

Initially, the 'distant cultivation model' was proposed for Çatalhöyük based on the lack of extensive cultivable land near the site on one hand (Rosen and Roberts 2005) and the predominance of dry land weed flora and their significant numerical correlation with crop products and by-products on the other (Fairbairn *et al*. 2002). Subsequent re-consideration of geological and geomorphological data suggested a slightly different picture where the Çatalhöyük environment would have included more dry land in the form of marl ridges and levees suitable for cropping (Fairbairn 2005). In this modified perspective, a combination of intensive (high labour inputs per unit area plus external inputs such as manure) and extensive (small labour inputs per unit area) land-management was proposed as a way of overcoming the deficiency in suitable (dry) cultivation areas (Fairbairn 2005: 205): intensive cultivation would have been practised on fields adjacent to the site, the size and extent of the plots limited by surrounding marshland; cultivation in the distant dry zone would have had to be extensive. These two strategies may not have developed at the same time and from the onset of occupation at Çatalhöyük; rather, they were temporally and spatially 'determined by the availability of productive land, crop requirements, husbandry technologies and labour availability' and ultimately, they 'reflected environmental and social conditions' (Fairbairn 2005: 198). As yet, however, neither of the two proposed models has been demonstrated conclusively on the basis of the Çatalhöyük archaeobotanical evidence.

Recently, a model of intensive mixed farming has been proposed for the dry-farming regions of the Near East (Bogaard 2004b, 2005), which implies small-scale intensive crop cultivation integrated with intensive small-scale herding. The model is based on archaeobotanical (ecological analysis of arable weeds) and ethnographic evidence (relating to small-scale subsistence farmers) for agricultural practices such as intensive tillage, manuring and cereal-pulse rotation, applied in order to enhance soil-productivity and crop yields (Bogaard *et al*. 1999), and has been tested against archaeobotanical arable weed assemblages and other archaeological data in central and south-east Europe (Bogaard 2004a, 2004b, 2005; cf. Halstead 1989, 2000, 2006). It is argued that this integrated farming system developed in the Pre-Pottery Neolithic B period, alongside the emerging Neolithic crop and livestock package, and in the context of large settlements where distance to furthest cultivation plots posed a significant challenge to early farmers (Bogaard and Isaakidou 2010). In the case of

'megasites' such as Çatalhöyük, the intensity of cultivation could have dropped off with distance from settlement, creating a continuum from highly intensive farming in a 'garden belt' around the site to relatively extensive/low-input farming at a greater distance (Bogaard and Isaakidou 2010).

This view of early farming is, in its very broad outline, in agreement with Fairbairn's (2005) perspective that the intensity of arable land management would have varied significantly in relation to the proximity of plots to the site; the reasons for the variability are, however, entirely different. The application of intensive farming techniques and close integration of crop and animal husbandry at Çatalhöyük would have represented a steady-supply food production system relying on high labour inputs and would have been largely independent of environmental conditions (e.g. intensity of flooding, quantity of rainfall, river channel shifting, extent of dry/cultivable land, soil quality) which were understood as the principal factors determining the viability/efficiency of agricultural production and its role in the foundation (e.g. choice of location) and expansion of the settlement (Asouti and Fairbairn 2002; Fairbairn *et al*. 2002, 2005a; Rosen and Roberts 2005; Roberts and Rosen 2009). The small-scale form of cultivation takes advantage of the potential of manure/midden material for creating a rich 'garden soil' over a restricted zone that can be intensively maintained (tilled and weeded manually) by a household, and that represents highly 'buffered' habitats for domestic plants and animals (Bogaard 2004a: 170, 2004b, 2005; Bogaard and Isaakidou 2010). The model does not presuppose distant cultivation, e.g. in the uplands more than 10 km away, and suggests full-scale utilisation of (limited) arable land around the site.

2.3.2.5 **Summary**

Present-day landscapes in Central Anatolia are a result of geomorphological evolution prior to and during the Holocene caused and ruled by variations in the climate (e.g. rise in humidity in the Early Holocene, with a shift to dry conditions later on), geological processes (erosion and accumulation), and impact from human use of soils, vegetation and water, particularly in the recent times. During the late Quaternary the Konya plain was largely covered by a shallow but extensive lake that, after *c*. 17,000 BP, started contracting and transforming into smaller lakes and marshes, and disappeared by the beginning of the Holocene. Throughout the Early Holocene alluviation from the Çarşamba river resulted in significant deposition over the large area of the plain, of levees and backswamps which covered, or interlocked with

the impermeable lake marl. The evidence from geomorphological coring in the 1990s was used as a basis for landscape reconstruction that saw the alluvial zone around the site as more or less continuous wetlands resulting from seasonal (spring) flooding of the area and large-scale deposition of alluvium on top of the water-retentive soil, lack of natural drainage (hence high water table), and generally flat terrain (meaning no dry land in the vicinity of the site). The model further implied that Çatalhöyük's location was unsuitable for agriculture and hence that crop cultivation was of lesser importance for subsistence, the primary focus being on wild-plant resources, high mobility of the inhabitants (aimed at tending of remote crop fields and sheep grazing on distant pastures in the uplands), and overall separation/independence of crop and animal husbandry.

A different picture of the alluvial environment, particularly in the immediate vicinity of the site, emerges from the evidence from recent excavations and geomorphological investigations (off-site coring). It appears that the sedimentation and soil distribution around the site was much more complex, and the topography uneven, suggesting (more) cultivable higher ground available nearby. The ecotonal location of the settlement between the former lake-bed and alluvial land may have been highly favourable for a range of activities, including cultivation, foraging, herding, exploitation of clays, firewood collection. The period between 10,000 BP and 8000 BP (the Early Holocene), overlapping with the beginning and most of the Çatalhöyük occupation, was characterised by a stable climatic regime with high precipitation levels (unlike those prior and subsequent to it); these conditions imply that, at the time of Çatalhöyük habitation, rain-fed agriculture was possible in the Konya plain.

Chapter 3 Methodology

This chapter sets out the methods used to recover, assess, select and analyse an archaeobotanical assemblage from recent excavation seasons at Çatalhöyük with a view to answering the research questions defined in Chapter 1. Sections 3.1 and 3.2 discuss the field and laboratory methods, respectively, used in the 1995-2003 excavation seasons. The process of sample selection for this project is described in Section 3.3, followed by sections on sorting, identification and quantification of the plant remains. Subsequent sections present the statistical approaches and ecological and experimental data used to guide the interpretation of the archaeobotanical dataset.

3.1 Field methods: sampling and flotation

The following is a summary of information pertaining to archaeobotanical methods applied in the field and published in Çatalhöyük annual archive reports (http://www.catalhoyuk.com), in the report on the methodology in excavation seasons 1995-1999 (Hastorf 2005) and in the archaeobotanical report from 1997-2003 excavations in the BACH area (Cane *et al*. 2012).

Initial analysis of macro-botanical material at Çatalhöyük (Helbaek 1964) revealed that the general mode of preservation of plants was by charring. Therefore, from the start of the new excavations flotation was the main method of recovery of plant remains (Hastorf 2005). A total of 3905 samples were processed from the 1995-1999 excavations in the South, North and KOPAL areas, and 1421 samples from the 1997-2003 excavations in the BACH Area (Hastorf 2005; Cane *et al*. 2012). The seed recovery potential of the two machines was tested over a couple of seasons using modern charred coriander seeds; both machines had the recovery rates of between 95% and 100% (Hastorf 2005).

Flotation samples were systematically taken from every excavation unit so that all contexts encountered would be represented and available for analyses and comparisons. 'Bulk' samples were regularly taken from units containing one distinct, homogeneous deposit. Where units comprised more than one type of deposit, or the matrix was heterogeneous, an attempt was made to take multiple flotation samples ('scatter samples'), in order to monitor variability within the unit (Hastorf and Near 1997). No artefacts were removed from the soil

prior to flotation, except for the artefacts declared 'x-finds' (e.g. figurines, bone and stone tools etc). The targeted volume of samples was 60 litres in the 1995 and 1996 seasons, but the flotation of these samples turned out to be very time-consuming; from 1997 onwards a standard sample size of 30 litres was established for flotation. This volume was a compromise between a smaller size (20 l), preferred by excavators, and a larger one (60 l), considered more representative by the site specialists (Hastorf 2005). A relatively large standard sample volume (30 litres) across the site increases the chances that statistically representative numbers of botanical (and other) remains are recovered even from relatively 'poor' (low density) deposits. However, there is no guarantee that a standardized volume will provide comparable numbers of remains per sample, since density is not dependant on volume; rather, it is often necessary to process different quantities of deposit from different contexts in order to retrieve numbers of items suitable for numerical analyses (Jones 1991: 66). Many excavated units (such as floors, hearth lenses, bin fills, caches etc) were not large enough to provide 30 litres of soil and here all available soil was taken for flotation.

Samples were processed using two flotation machines set up at the edge of the mound. A smaller machine was used for processing samples smaller than *c.* 20 litres, while a larger machine was used for samples with more than *c.* 20 litres of soil. In both machines *c.* 0.5 mm aperture meshes were used for collecting heavy residue, and *c.* 0.17 mm aperture chiffon for the light residue (floating fraction) (Hastorf and Near 1997). If a unit contained more than 30 litres of soil, the remaining matrix was dry-sieved using a 4 mm mesh and visible artefacts and plant remains (mostly wood pieces and tubers) were collected. The plant remains from the dry sieve ('screen botanicals') were kept and analysed separately from the light and heavy fraction. Dried heavy and light residues were taken to the on-site archaeobotanical laboratory for analysis. A group of Turkish women from the local village of Küçükköy and the town of Çumra were trained to sort heavy fraction, while one or two archaeologists oversaw their work and prepared samples for sorting (splitting, labelling, bagging and weighing of the material).

3.2 Previous sample assessment and analysis

Heavy fractions of samples were sieved for >4 mm, >2 mm and >1 mm subfractions and then sorted for material such as bone, stone, plant, eggshell, bead etc. The >4 mm subfractions

were completely sorted, while >2 mm and >1 mm subfractions were further subsampled, usually to 1/2 and 1/4, respectively. The material extracted was distributed to specialists for analysis.

The team that oversaw archaeobotanical fieldwork at Çatalhöyük during the years 1995-2002 developed a three-phase analytical procedure for light fraction of samples. In Phase I, the entire sample was 'scanned' to record general composition: presence, abundance and diversity of 'organic classes' (cereal grain, chaff, pulse, wild seed, nut shell, fruit, hackberry, wood, dung, bone etc) as well as the state of preservation of 'plant classes'. The aim was for all the samples to undergo this stage. In Phase II, the sample was sieved into >4 mm, >2 mm, >1 mm and >0.5 mm fractions, each of them weighed and sometimes sub-sampled to speed up the analytical process. Botanical remains (including those from heavy fraction) were extracted, counted and weighed by plant class. In the final phase (Phase III), all plant remains were identified to, where possible, family, genus or species level, and counted.

For samples from 'priority units' (i.e. of special importance, see Farid 2000) a slightly modified Phase II analysis was developed, which included sorting of the remains from 4 mm and 2 mm fractions, identification to plant categories, and counting; smaller fractions (1 mm and 0.5 mm) were scanned and present plant classes noted. Based on these observations, the sample's overall density and composition were roughly estimated. This information was used to provide 'quick feedback' to excavators and other specialists, with the intention of carrying out Phase III analysis of the samples at a later stage (Hastorf 2005).

Four hundred and twenty-one samples from the North, South and KOPAL areas were analysed to Phase II (most of them from units prioritised in the field), and another 77 to Phase III (Fairbairn *et al*. 2005a). Samples were selected for phase II-III analysis based on their archaeological context, so as to investigate the botanical content of a wide range of unit types excavated and to obtain data on the general composition and distribution of plant remains. Results of the analysis and their interpretations are published in detailed reports by members of the previous Çatalhöyük archaeobotanical team (e.g. Fairbairn *et al*. 2002, 2005a; Fairbairn 2005).

From the BACH Area 201 samples were analysed (only) to Phase II. Of those, 134 samples from the excavation seasons 1997-2003 were chosen based on their 'contextual evidence,

excavator preferences and research questions' for completing multivariate numerical analysis (correspondence analysis, principal component analysis, discriminant analysis etc) using only general identification categories (e.g. cereal, pulse, chaff, seed, nut - Cane *et al*. 2012: Fig. 9.1) and aimed at detecting possible patterning in contextual distribution of plant remains in the building (Building 3) excavated by BACH team (Cane *et al*. 2012).

While the sampling strategy and flotation techniques have remained the same since archaeobotanical work was initiated in 1995, laboratory procedures were refined through time in order to follow newly developed standards in archaeobotanical practice and also to meet the demands of the research process at the site (e.g. recording as many details as possible efficiently). From the 2003 field season onwards, a new on-site laboratory procedure was introduced (Ağcabay *et al*. 2003). Instead of conducting Phase I analysis in the field and looking in more detail only at priority samples, a rapid assessment procedure (i.e. sub-sampling and identification to crop type and plant part) was applied to all samples 'in order to estimate their botanical composition and richness' (Ağcabay *et al*. 2003) on the basis of which samples are selected for further analysis (i.e. full-sort and identification). Both priority and non-priority samples receive the same treatment in this initial stage of analysis and, compared to the previous Phase I-II/priority sort procedure (applied to BACH samples in season 2003), the new method proved to be more efficient in providing useful information on richness and type of identifiable plant material for all flotation samples, with more accurate estimates of quantities and density for priority samples (Ağcabay *et al*. 2003; Bogaard *et al*. 2004, 2005a, 2006). The incompatibility of data in earlier studies with that of the present, due to differences in analytical methods, means that a direct comparison, by the means of multivariate statistics, has not been possible between the two datasets.

3.3 Selection of samples for the present study

As discussed in Chapter 1, one of the main research questions that this project is designed to address is the nature of agricultural production at a large early farming tell-site in south-west Asia. In order to be able to discuss this and other important issues of plant use and crop husbandry at Neolithic Çatalhöyük, relevant sample selection criteria were applied, based on botanical and archaeological characteristics of the samples.

Archaeobotanical samples from the completed phases of excavation in the South, North and KOPAL areas (1995-1999 field seasons) and in the BACH area (1997-2003 field seasons) of the Çatalhöyük East constituted the 'pool' of samples available for selection. Samples from these particular areas and phases of excavation were of interest for several reasons. First, major sequences and/or buildings in these areas were completely excavated; for example, the base of the mound (i.e. the earliest levels) was reached in the deep sounding in the South Area, while in the North Area Building 1 was excavated in its entirety. Building 5, underlying Building 1, was partially investigated (down to the occupation phase B5.C, pre-dating final occupation phase B5.B) and exposed floors, walls and interior features were prepared for public display in 1999 (Cessford 2007b). Similarly, the Konya Basin Palaeoenvironment (KOPAL) team research project ended in 1999 and the results were published (e.g. Roberts *et al*. 1996, 2007; Boyer *et al*. 2006). In the BACH Area, Building 3 was completely excavated, with the exception of one of three small abutting rooms (Space 87) considered part of the building, where excavations continued in later years (Tringham and Stevanović 2012).

Overall, the 1995-2003 excavation areas offer good spatial coverage of the lower to middle occupation levels (Pre-Level XII-Level VI/South G-South N) of the Neolithic sequence at Çatalhöyük; moreover, understanding of the archaeology and interpretation of the investigated structures and features benefited significantly from the post-excavation analysis. From 2000 to 2002 post-excavation work for the South, North and KOPAL areas was carried out through summer study seasons at the site, allowing teams of specialists working on different types of material to discuss and compare their observations. Subsequently, the results of the excavations, including stratigraphy, phasing and absolute chronology, were published in four major volumes in 2005-2007 (Hodder 2005a, 2005b, 2005c, 2007). As part of this process, data on units excavated in this period were revised and, if necessary, amended in the Çatalhöyük Excavation Database and one of ten general 'data categories' (i.e. context types) assigned to each of them (Farid 2007). Post-excavation study of the BACH Area commenced in 2004 and was completed in 2010 (Tringham and Stevanović 2012).

Altogether, a large archive of 4151 archaeobotanical samples from the targeted areas and phases of excavation were available for the analysis encompassed by the present study. This assemblage included unanalysed samples and those analysed to Phase I and Phase II from the 1995-1999 excavation seasons in the South, North and KOPAL areas and the 1997-2003 excavation seasons in the BACH Area. As noted above, Phase I analysis provided only basic

data on the presence/absence of general plant categories ('classes'), while in Phase II these general plant types were recorded by count and weight (Hastorf 2005). This information offered a broad overview of the botanical content of a sample, but not the thorough insight into the occurrence of specific crop and wild taxa needed for the purpose of this project. Given that they were completely analysed (sorted, identified and counted), Phase III samples were excluded from consideration.

From the outset of this project it was clear that not all of the available samples merited detailed examination. Only samples from well-defined depositional events and containing a significant amount of identifiable/scoreable plant remains (other than wood charcoal) required for statistical analysis could provide data useful for the current investigation. In order to assess the 'suitability' of the samples, appropriate archaeobotanical and archaeological selection criteria were applied and the selection proceeded through three stages - scanning, consideration of archaeological context and sub-sample study.

3.3.1 **Scanning**

At this stage of the selection the aim was to determine the (potential) botanical richness of the more than 4000 available samples and to exclude from further consideration those that were (very) poor in botanical remains. Therefore, the samples were 'scanned' by rapidly assessing each sample bag by eye without opening it, except when a sample was obscured by modern roots or was split and fractions put in separate bags (i.e. the samples previously analyzed to Phase II). The samples were given a score of '1' for estimated *c*. 0-50 identifiable items, '2' for *c*. 50-500 identifiable items and '3' for more than *c*. 500 identifiable items. Using this abundance scale, score '1' was assigned to 2151 samples, score '2' to 1554 samples and score '3' to 446 samples. Score '1' samples were at this point excluded from further consideration as they were too poor to provide reliable representations of the sampled populations (cf. van der Veen and Fieller 1982). Score '2' and '3' samples were numerous (a total of 2000) and derived from archaeological deposits of variable interest for this study. A further stage of selection, involving assessment of archaeological contexts, was therefore undertaken.

3.3.2 **Archaeological context**

The next stage of the sample selection focused on the archaeological contexts of the 2000 samples with scanning score '2' or '3'. As mentioned, plant remains from Çatalhöyük are in most cases preserved by charring (Helbaek 1964; Fairbairn *et al*. 2005a, 2007; Hastorf 2005). Thus, if a concentration of botanical material occurred at a burning spot or adjacent to it, and did not seem to have been disturbed by subsequent activities/mixing, it was considered to be a 'primary' (*in situ*) (Miksicek 1987) deposit related to a burning event and linked with its spatial location (cf. Hodder *et al*. 2007: 23). Primary/*in situ* deposits represented the highest priority for the present investigation; they included units associated with fire installations (ovens and hearths), 'rake-outs' (occupation floors near fire installations, in the 'dirty' zone of houses), contents of bins and basins (if it appeared that they were burnt *in situ*), 'fire spots' (burnt/scorched patches with ashy fill, usually external) and other discrete, 'single-event' deposits considered to have been rapidly buried ('sealed'). 'Secondary' or 'tertiary' deposits (mixed/disturbed, e.g. midden, building fill, pit/cut fill) lacked evidence of *in situ* burning by definition, meaning that their charred botanical content had been re-deposited from elsewhere and would be more difficult to link to a distinct event/practice. The majority of the 'rich' (score '2' and '3') samples came from non-primary deposits. At this point, the nature of the event(s) or practice(s) to which a context was related was not of major concern; rather, the evidence that a specific botanical assemblage indeed resulted from a single event/activity *or* similar events/activities repeated over time was considered relevant to the present study. Therefore, both samples from primary and secondary/tertiary deposits were included in the process of further selection.

In order to assess which units/samples from primary and secondary/tertiary contexts could be indicative of specific human activities, data available in published works, databases, diaries and other sources were assembled and discussed with team members (e.g. Hodder 2007; Tringham and Stevanović 2012; http://www.catalhoyuk.com). Fairbairn *et al*.'s (2005a) observations were used as broad guidelines. Their analysis showed that context types such as floors, building materials (bricks and mortar) and fills from cuts, pits, burials and between walls contained very low botanical densities (compared to the general density pattern) and that preservation of plant remains extracted from these deposits was usually poor. Building fills, packing (material used in construction), units from oven/hearth use and penning areas had moderate botanical densities, while larger and better preserved quantities of plant

remains were found in rake-outs, external middens and fire spots, and especially in burnt storage units (from Building 1, North Area). On this basis, samples from a majority of the unit types (e.g. fill between walls, building material, burial fill, floor) with low botanical density and low interpretative potential were *a priori* excluded from further consideration and they are not discussed here. What follows is a summary of the archaeological characterization of unit types from which the samples selected for further study were retrieved.

3.3.2.1 **Selected unit types**

Selection of unit types for potential analysis was based upon the general archaeological interpretation of various contexts and descriptions of each relevant individual unit in the database (http://www.catalhoyuk.com/database). Descriptions of the 'data categories' (Hodder 2005: Fig. 1.3) into which selected units were classified is given below, beginning with those recognised as primary deposits, followed by summaries of secondary/tertiary deposits. Observations on previously analysed botanical assemblages from these context types were taken from Helbaek (1964), Fairbairn *et al*. (2005a, 2007) and Cane *et al*. (2012).

Fire installations

This category comprises (domed) ovens and hearths which are characteristic of all excavated houses at Çatalhöyük East (Mellaart 1967; Hodder 2007). It is assumed that the botanical content of these contexts represents remains of food, fuel and burnt rubbish and is therefore related to specific activities (e.g. food preparation), though some of the plant parts potentially derived from material used as temper in oven superstructures (Fairbairn *et al*. 2005a). Previously analysed samples contained a variety of material (cereal grain and chaff, wild seed, wood) but were in most cases of a low density, which suggests that fire installations were usually kept clean while in use, although occasionally charred 'fill' was encountered.

Rake-outs/ashy spreads

In close proximity to hearths and ovens occupation floors often appeared 'dirty' with accumulated ashy spreads or rake-outs on top of them. These deposits represent the build up of ashes resulting from use of ovens and hearths, sometimes trampled into the floor surface, which was periodically cleaned out. Apart from the remains of fuel, they could preserve food preparation debris or food. Samples from these contexts often contained relatively high

densities of botanical remains, higher than 'clean' floors and fire installations (Fairbairn *et al*. 2005a).

Bins and basins

From an archaeobotanical point of view, structures defined as bins and basins are potentially interesting, as they may have served for storage or processing of food (Atalay and Hastorf 2005, 2006). Stored plant material was occasionally burnt *in situ*, as in a bin/basin fill from Building 1 (North Area), where a significant concentration of charred lentils was discovered (Fairbairn *et al*. 2005a), or in bins full of charred cereal grain or crucifer seed stores recovered from various stratigraphic levels in Mellaart's excavations (Helbaek 1964: 121; Fairbairn *et al*. 2007: 468), and in burnt bin-stores of cereal grain, peas, crucifer seeds and almonds from Building 52 (4040 area) excavated in 2005 (Bogaard *et al*. 2005a). Botanical evidence from Building 3 (BACH area) seems to indicate that basins may have been used for some form of food processing (e.g. soaking, fermenting) rather than storage (Cane *et al*. 2012).

Clusters and caches

Clusters are concentrations of artefacts or ecofacts (e.g. obsidian, animal bone, clay balls, charcoal/seed - Hodder *et al*. 2007: 14). Non-botanical clusters sometimes occur with charred plant inclusions (e.g. samples from around obsidian cluster in Building 2, Space 117, contained dense charred plant material – Fairbairn *et al*. 2005a; fruit, cereal and tuber remains associated with clay ball cluster in Building 3 - Cane *et al*. 2012). In some cases, animal bone clusters have been interpreted as potential feasting remains (Russell and Martin 2005); the composition and quantity of associated plant remains may have implications for the, as yet unclear, role of plants in the proposed (social) events of feasting (Fairbairn *et al*. 2005b: 11).

Caches of seeds were occasionally found, as perhaps further evidence of storage (Cane *et al*. 2012), sometimes also interpreted as 'offerings' (e.g. grains and crucifer seeds in front of the leopard relief in the 'Leopard shrine'- Mellaart 1964: 45). Caches of plant remains were also found within contexts such as middens and building fills, where their deposition was considered secondary - possible debris from meals/feasts (Fairbairn *et al*. 2005a).

Penning

Penning areas were discovered in Space 198 (Level XI/South I) and Space 199 (Level XII/South H) in the 'deep sounding', and in space 117 of Building 2 (Level VIII/South L) in the South Area. The deposits believed to represent remains of stabling consisted of a 'mixture of animal coprolites, dung pellets, spherulites, spreads of plant material which left phytoliths impressions and thin bands of dumped clayey material' (Farid and Cessford 1999). It was suggested that pens provided shelter for animals during winter months (Matthews 2005b). Possible penning areas might have existed in external middens as well (see Farid 2007: 241). Botanical assemblages from these areas contained large quantities of charred cereal grains and chaff, and wood charcoal; since no *in situ* burning was recorded, charred remains likely constitute re-deposited material. In addition, a considerable amount of mineralised seeds was found that could derive from original (*in situ*) deposition; mineralisation is a common form of preservation of organic matter in latrine deposits due to high mineral (e.g. calcium, phosphate) content in these contexts (Green 1979; Shillito *et al*. 2008). Mineralised seeds in penning areas probably represent remains of dung, fodder or bedding for animals (Fairbairn *et al*. 2005a; Cessford 2007a: 94).

External floors

In phase South G (in Pre-Level XII.B-C) in the South Area deep sounding, possible surfaces in the form of hard clayey layers were discovered in an 'external midden' in Space 181, where no visible structures were detected. These surfaces were interpreted as external floors where various activities, including *in situ* burning, probably took place (Cessford 2007a: 70-73), and they are therefore considered primary deposits.

Roof

Remains of a collapsed roof were identified based on micromorphological analysis of segments of multiple layers of thick plaster and mud packing in Building 3 in the BACH Area (Matthews 2005a; 2012) and in Building 5 of the North Area (Cessford 2007b: 383; Matthews 2005a). The roof collapse in Building 3 was associated with a thick layer of ash, perhaps also originating from the roof (i.e. remains of mats or reed and rushes used in roof construction - Matthews 2005b). An oven base and rake-out material was recognized in micromorphology samples from Building 3 roof serving as an evidence of activities that took place on rooftops; presence of an 'upper storey' room was also suggested (Matthews 2005b, 2012).

Archaeobotanical analysis of roof collapse samples from Building 3 detected a high density of cereal remains, especially grain, and this, combined with the presence of 'dark discrete layers within the large pieces of roof collapse' was seen as possible indication that the roof was used for 'the final stages of food processing of cleaning winnowed stores and/or for food preparation' (Cane *et al*. 2012).

Middens

Middens represent waste disposal areas and are therefore rich in artefacts and other types of finds (Mellaart 1967: 62; Hodder *et al*. 2007: 17). Deposits within them are considered secondary or tertiary and represent periodic dumping of cultural debris from a wide range of activities, often visible as fine layers representing single depositional events (Farid 2007: 242). Middens are usually located outside built structures, in 'open spaces' which Mellaart termed 'courtyards' (Mellart 1967). In the course of the recent excavations, it was discovered that they usually represent (or at least start as) infill of abandoned buildings, meaning that disused structures were actually still in use as rubbish disposal zones (the exception is the midden in Space 181 in the South Area phase Pre-Level XII/South G, which was placed on natural soil; Cessford 2007a: 60). In cases of their prolonged 'use' through time, middens expanded beyond the limits/walls of underlying structures, and covered a larger area. Space 115 in the South Area is one such example where external midden started accumulating on top of and within limits of an earlier midden in abandoned Building 2, but then expanded beyond it (Farid 2007: 242, 315).

Despite their general use for rubbish deposition (e.g. ashy fills cleared out of ovens and hearths), some activities did occasionally take place in middens (e.g. on external floors). Evidence in external middens of informal burning (e.g. fire spots) was recorded (and in some instances in Space 181 interpreted as burning of lime for floor and wall plastering - Cessford 2007a: 83), as well as obsidian-knapping, crop processing (parching), animal penning (Cessford 2007c; Matthews 2005a), and possibly manufacture of bricks and mortar (Martin and Russell 2000: 64). Quarrying/pit-digging in middens for material to be used as mortar and packing, or for broken-down building material (bricks and mortar) for the use in house and feature construction (as material for floor-packing) and in-filling (of e.g. cuts and abandoned buildings) also took place in these open spaces. New buildings were sometimes built on top of external middens (e.g. Building 40 in Space 115 - Farid 2007).

Middens in abandoned buildings usually overlie and/or are mixed with building debris. For example, if a new structure was to be built on top of an old one, the older structure would, if necessary, have been filled in with material from neighbouring (external) midden(s) for elevation and used as foundation for new-built structure. Such fill deposits were interpreted as tertiary contexts (e.g. Building 2 in the South Area - Farid 2007).

Overall, middens can include primary (*in situ* burning, penning, latrine deposits etc) and secondary deposits (displaced refuse of diverse origin); tertiary deposits are found on top of or within fill of abandoned buildings. Previous botanical work suggests that plant remains in middens usually derive from re-deposited fire installations fills and rake-outs (sometimes visible as distinct ash lenses), unless *in situ* burning occurred (fire spots). Botanical diversity tends to be high in middens and the remains are abundant and well preserved (Fairbairn *et al*. 2005a).

Fills

Fill of cuts of variable function are considered tertiary deposits as they usually appear to represent re-deposited midden material. Previous archaeobotanical analysis has shown that they tend to contain small quantities of plant remains (as opposed to middens, rich in organic debris), probably because they were mixed with rubble from building fill or flooring (Fairbairn *et al*. 2005a).

In some cases, foundation trenches (cuts for wall construction) contained distinct organic deposits as in, for example, Space 105 in the South Area (Farid 2007: 304). Here, overlying the basal layer in the foundation cut was a bone cluster interpreted as evidence of feasting, a ritual perhaps related to house construction (Hodder *et al*. 2007: 27); however, as noted before, the role of plants in feasting has not yet been explored. In cases where a foundation trench was cut into midden (e.g. Building 40 in the South Area with walls cut into midden in Space 115), plant and other remains encountered at the base of the walls were in fact part of the surrounding midden deposits (Farid 2007: 316). This is supported by the results of previous analysis of fills of wall foundations cut into middens; similar to middens, the samples had relatively high botanical densities (Fairbairn *et al*. 2005a).

Building fill represents material with which a space or a building was filled after it went out of use. It usually contains collapsed roof debris and wall rubble and represents a base for

construction of a new building on top. Mudbricks and mortar from (upper portions of) walls were crushed and maybe even sieved, and placed in the interior of the old structure. On some occasions material from midden was added on top to provide more solid and elevated foundations (Farid 2007: 52). With the exception of fill from Building 1 (Cessford 2007b), there was no sign of burning in any of building fill samples previously analysed, and their botanical content is probably of secondary/tertiary origin. In parts of building fills directly above floors, a different composition of plant remains compared to that of the rest of the fill was noted, probably because some of the floor occupation (activity) debris was incorporated (Fairbairn *et al*. 2005a).

Packing

Packing usually consists of building or midden material re-used for construction of different architectural elements (floors, roof, wall blockings, etc) and features within a house (Hodder *et al*. 2007: Fig. 1.4). Plant remains from this type of deposit were of moderate density and re-deposited from elsewhere, as there was no sign of burning in the sampled units (Fairbairn *et al*. 2005a). Of greater interest is packing from 'dirty' areas of houses, where food preparation took place and where residue from this and various other activities accumulated and was trampled into construction material (Hodder *et al*. 2007: 17; Farid 2007: 57).

Natural sediments

Natural deposits are not of primary analytical interest, unless, as in the case of some of the units in the 'off-site' KOPAL trench, they contain cultural material (Roberts *et al*. 2007). Animal bones, plant remains and various artefacts were discovered in the deposits originally thought to be of alluvial origin, and they are interpreted as 'waste cultural material deposited in worked-out marl pits'. A high concentration of silicified awns in one of the pit-features deposits may suggest that early-stage cereal processing (i.e. threshing) took place in the area around the edges of the settlement (Roberts *et al*. 2007).

3.3.2.2 Summary of samples selected by unit types

A total of 362 score '2' and '3' samples (i.e. estimated to contain at least 50 identifiable plant remains) were selected on archaeological grounds for potential analysis. Table 3.1 illustrates how this number breaks down into 'data categories' or context/unit types. The samples from bins/basins represent in most cases fills of these structures, with the exception of a few

botanically rich ones from bin floors and walls. Selected cluster samples comprise soil surrounding concentrations of other material (e.g. obsidian, bone, clay ball), or represent concentrated botanical material. Nineteen samples from 11 units excavated in three penning areas (Spaces 117, 198 and 199) were included in further analysis. The selected external midden samples belong predominantly to deposits with recognized ash lenses or burning events in Spaces 181 and 115 in the South Area and Space 85 in the BACH Area. Twenty two samples originating from midden in abandoned buildings was included at this stage of selection due to their botanical richness. The majority of 'building fill' samples derive from Building 1 units that comprised concentrations of charred plant remains above floor, or ash lenses in rubble. The eight cut/pit fill samples were rich enough to be considered for further study, as were two samples from foundation cut fills, and four samples from units resulting from constructional activity (make-up/packing). Two samples selected from the KOPAL off-site trench (located to the north of the East Mound) came from a unit initially interpreted as mixed alluvium (natural sediment) which in the course of excavation turned out to contain various archaeological finds (animal bone, chipped stone, etc) and a high concentration of carbonized plant remains (Roberts *et al*. 2007: 563).

Context type	Number of samples
OVEN - fill and/or floor	44
HEARTH	24
RAKE-OUT/ASHY SPREAD	72
BIN floor, fill, wall	20
BASIN floor, fill, wall	6
CLUSTER/CACHE of obsidian/bone/clay ball/charcoal	9
PENNING	19
EXTERNAL FLOOR OCCUPATION	3
EXTERNAL MIDDEN (inc. ash deposits/burning events)	95
ROOF (collapse)	4
MIDDEN IN ABANDONED BUILDING	22
CUT/PIT FILL	8
FILL OF FOUNDATION CUT	2
BUILDING FILL	27
CONSTRUCTION (make up/packing)	5
NATURAL SEDIMENT	2
total	*362*

Table 3.1 Summary by context type of the samples with scanning scores '2' and '3' selected on archaeological grounds as potentially interesting

3.3.3 **Subsample study**

On the basis of archaeological context, 362 samples were considered to derive from deposits that are potentially informative of plant-related activities (e.g. plant processing and storage, food preparation) and/or to represent *in situ* burning and hence of interest to this study. As samples with a scanning score of at least '2' (see Section 3.3.1, above), they were estimated to contain more than 50 identifiable/scoreable plant remains (excluding wood charcoal). In order to address the research questions, a minimum level of richness in crop *and* wild remains was desired. Estimates of the amounts of identifiable crop and wild items for individual samples were obtained by sorting a random light fraction ('flot') subsample for each sample.

The flots were first sieved to >4 mm, >2 mm, >1 mm and >0.3 mm fractions using a set of geological sieves. The 1 mm fraction appeared to contain most of the material; it was split using a sample divider (riffle-box) to get a random subsample of *c*. 10 ml in volume; subsamples ranged from 1/2 of small samples, to 1/64 of large samples. Random subsamples were fully sorted for crop and wild plant remains and the approximate number of items estimated through rapid counting. On the basis of subsampling results, the number of different items for the entire 1 mm fraction of each sample was calculated by multiplying the estimated numbers by the appropriate factor (e.g. if 1/4 of 1 mm was sorted, the estimated number of crop/wild items was multiplied by four to obtain the number for the whole 1 mm fraction). Thus, the potential richness of all selected samples was estimated in a much less time-consuming way than full sorting (i.e. sorting of 100% of samples).

Richness estimates based on the subsample study were compared among the samples and arbitrary minimal thresholds required for full analysis were established for crop and wild material: in order to be selected for full analysis, a sample had to contain an estimated total of 1) at least 100 crop items *and* 30 wild plant seeds, or 2) at least 100 wild plant items. Both the initial (the 1960s) and subsequent (the 1990s) archaeobotanical analysis demonstrated that the remains of crops dominate the assemblage (Helbaek 1964; Asouti and Fairbairn 2002; Fairbairn *et al*. 2002, 2005a); thus a minimum of 100 crop items per sample was considered a reasonable expectation for a large number of samples. On the other hand, from the results of previous work by Fairbairn *et al*. (2005a) it was clear that wild plant seeds often occurred in lower amounts, even in relatively 'rich' contexts such as middens. Therefore, a lower arbitrary threshold of 30 wild plant seeds was used for the samples selected under the first

criterion where wild seeds are potentially associated with crops (as arable weeds) and could be used to address ecological aspects of crop growing; 30 items is a statistical minimum for any analysis (e.g. Rowntree 1981). The second criterion was intended for the selection of samples rich in wild seeds but not containing much crop material, as might be expected for collected wild material (Fairbairn *et al*. 2007) and/or dung-rich deposits (Fairbairn *et al*. 2005a).

The richness criteria were applied to the 362 samples, using the estimates obtained through the subsample study. A total of 115 samples from 93 units were identified as 'rich enough' to provide an adequate basis for achieving the research goals. Table 3.2 shows the distribution of the selected samples and units across different archaeological contexts, structures and occupation phases of the East Mound. Of the eight included phases, the majority is represented by ten or more samples often deriving from more than one Space/Building. The recognised sequences of superimposed structures in the South Area ('stacks' or 'columns' of buildings - Farid 2008) which stretch through multiple building phases (Levels/phasing strands) are reasonably well covered by the selection of samples (see Fig. 3.1). Similarly, in the North Area (inc. BACH) samples from both Building 5 and Building 1 built on top of it yielded samples for the analysis, as well as the neighbouring Building 3. Table 3.3 shows distribution of the selected samples across the building sequences. The growth of the settlement appears to have been steady over the occupation phases encompassed by the present study (Mellaart 1967). The plant evidence from the successive superimposed buildings is here seen as crucial for investigating repeated patterns and continuity in the range of exploited plant sources and the ways in which they were used through time, as indicated in previous archaeobotanical analysis (Fairbairn *et al*. 2005a), as well as detecting any potential temporal change in plant husbandry (and in different parts of the settlement).

3.4 Sorting of the selected samples

The selected samples estimated to contain the desired amount of at least 100 crop remains and 30 wild plant seeds, or minimum 100 wild seeds, were subjected to detailed analysis, of which sorting was the first stage. Wood charcoal, cereal grains and chaff, legumes, wild seeds, reed (and cereal) culm nodes, tuber/parenchymous tissue and nut shell/fruit stone fragments were extracted.

Area		*SOUTH*																		*NORTH*					
Building (B) or Space (Sp.)		Sp. 181		Sp. 199		B. 23		B. 18		B. 17	B. 16	B. 2		Sp. 115		B. 4	B. 6	Sp. 105	Sp. 112	Sp. 109	Sp. 107/108	Sp. 160	B. 5		B. 1		B. 3 & Sp. 85	
Hodder phase		**SOUTH G**		**SOUTH H**		**SOUTH J**				**SOUTH K**				**SOUTH L**				**SOUTH M**				**South N?**	**North F?**		**NORTH G**			
Mellaart Level		Pre.XII		XII		X				IX				VIII				VII				VIb	VII/VI?					
Chronology (cal BC; Cessford 2005)		7400-7050		7080-6950		7050-6830				7000-6600				6700-6500				6620-6550				6600-6500	6620-6400					
Context	sample/ unit	sample	*unit*	sample	*unit*	sample	*unit*	sample	*unit*	sample/ unit	sample/ unit	sample	*unit*	sample	*unit*	sample/ unit	sample	unit	sample/ unit	sample/ unit	sample/ unit	sample/ unit	sample/ unit	sample	*unit*	sample	*unit*	sample	*unit*
OVEN - fill and/or floor										**1**																**8**	*7*	**3**	*3*
HEARTH						**2**	*2*																			**1**	*1*		
RAKE-OUT/ASHY SPREAD						**1**	*1*	**10**	*6*		**1**	**2**	*2*				**2**	*2*								**2**	*2*	**2**	*2*
BIN - floor/fill/wall								**2**	*1*			**1**	*1*				**1**	*1*								**3**	*2*	**2**	*2*
BASIN - floor/fill/wall												**1**	*1*				**1**	*1*								**3**	*2*	**1**	*1*
CLUSTER/CACHE of obsidian/ bone/clayball/charcoal														**1**	*1*				**1**										
PENNING				**3**	*1*							**2**	*2*																
EXTERNAL FLOOR OCCUPATION		**2**	*2*																										
EXTERNAL MIDDEN (inc. ash deposits/burning events)		**10**	*5*											**10**	*9*						**1**							**3**	*2*
ROOF (collapse)																												**8**	*5*
MIDDEN IN ABANDONED BUILDING												**6**	*6*																
CUT/PIT FILL																	**1**	*1*											
FILL OF FOUNDATION CUT																						**1**							
BUILDING FILL																**1**	**1**	*1*								**9**	*7*		
NATURAL SEDIMENT	**1**																												
total samples	**1**	**12**		**3**		**15**				**14**				**18**				**4**				**1**	**2**		**45**			

Table 3.2 Distribution of the selected samples and units across different archaeological contexts, structures and occupation phases of the East Mound

Level	Phase	North sequences							
VII/VI?	North G	B. 1	B. 3	Sp. 85					
VII/VI?	North F?	B. 5							
number of samples		*28*	*16*	*3*					
Level	**Phase**	**South sequences**							
VIB	South N		Sp. 160						
VII	South M					Sp. 109	Sp. 112	Sp. 105	Sp. 107/108
VIII	South L	B. 6				B. 4		Sp. 115	
IX	South K	B. 17		B. 16		B. 2			
X	South J			B. 18	B. 23				
XII	South H			Sp. 199					
Pre.XII	South G			Sp. 181					
number of samples		*7*	*1*	*28*	*3*	*14*	*1*	*12*	*1*

Table 3.3 Distribution of the selected samples across the sequences of buildings in the South and North (inc. BACH) excavation areas.

As mentioned in Section 3.3.3, flots were sieved to 4 mm, 2 mm, 1 mm, and 0.3 mm fractions in order to speed up the sorting process. The 4 mm and 2 mm fractions were sorted with the naked eye and then checked under a low-power (x7-45) stereoscopic binocular microscope; the 1 mm and 0.3 mm fractions were sorted under the microscope. Plant material recovered from heavy fraction (from subsamples of 4 mm, 2 mm and 1 mm) was also sorted. From 4 mm and 2 mm fractions of flots and heavy residue charred wood pieces and other plant remains (most often tuber/parenchymous tissue fragments, large-seeded pulses, larger cereal grains, dung pellets or fragments) were extracted. From 1 mm fractions of flots and heavy residue, and 0.3 mm fraction of flots all identifiable plant remains (seeds, chaff etc) except for wood charcoal and tuber were sorted.

In order to maximise the chance that the botanical composition of a sample accurately reflects that of an assumed infinite population of seeds in the sampled context, a minimum of 541 crop and 541 wild items would be needed from each sample (a minimum of 541 items per sample allows for a 98% chance of accurate estimates of the proportions of species in sampled contexts - van der Veen and Fieller 1982). Therefore, wherever possible, at least 400-500 crop items (and 30 wild), or 400-500 wild remains were targeted. As a result, the 2 mm and 1 mm fractions of most of the flots were sorted in their entirety (100%) in order to obtain as high number of crop or wild remains (i.e. as close to *c*. 500 items) as possible. For botanically 'rich' samples (i.e. containing much more than the required *c*. 500 crop or wild items) sorting of subsamples of 1 mm fractions (divided with a riffle box) was carried out.

Fine fractions (0.3 mm) were generally split to 1/8 of the sorted 1 mm fractions (e.g. if 1/4 of fraction 1 mm was sorted, then the fine fraction would be split to 1/32), sorted, counted and numbers of items multiplied up accordingly. Overall, fine fractions were poor in identifiable crop remains but often contained small wild plant seeds. In cases where a completely sorted coarse fraction (4 mm, 2 mm and 1 mm) had not yielded 30 wild seeds, a greater portion of the 0.3 mm fraction was sorted. In several samples, large quantities of small *Crucifereae* seeds were found in the 0.3 mm fraction; since it would have been too time-consuming to extract all of these from the required fine fraction subsample (1/8 of the sorted coarse fraction), smaller subsamples of the fine fraction were sorted for the crucifer seeds only (e.g. 1/64). In the case of 'rich' samples, the 1 mm fraction was also subsampled (to 1/2 or 1/4). A similar strategy was applied to the sample composed mainly of lentils, where a large number of them were present in the heavy fraction. The reasoning was that multiplying *large* numbers of seeds (e.g. 500) by a large factor is less problematic than multiplying up small numbers of seeds by a large factor, as this can severely distort their importance (N. Fieller pers. comm.).

Subsampling of the 0.3 mm fraction down to 1/8 of the sorted 1 mm fraction was used as a means of speeding up sorting of the very time-consuming fine fractions. The principle of multiplying the number of items in subsamples by no more than eight is an arbitrary rule designed to reduce the possibility of amplifying small inaccurate sub-samples leading to a distorted estimate of overall sample content. In terms of its effect on the multivariate data exploration (Ch. 5, 6) carried out on the basis of sample composition, any inaccuracies introduced through sub-sampling and multiplying are unlikely to create spurious patterns; if anything, they would be expected to obscure the kind of patterning that can be revealed through correspondence analysis (N. Fieller pers. comm.).

For groups of samples from the same unit, the richest/densest sample was targeted for analysis in the first instance, and often a random sub-sample was sorted in order to retrieve 400-500 crop (and 30 wild) or 400-500 wild plant items. Other selected samples from the same unit were then subsampled to the same fraction as the richest/densest one; in this way, the similarities/differences in the crop *vs*. wild presence and abundance in the individual samples, and across the whole unit, could be assessed (and a possibility of amalgamating samples from the same unit considered - see below). In cases where two or more samples were taken from the same unit merely due to its large extent (as indicated in the unit

description provided by the excavator), and not because they appeared to represent different deposits/event, they were all (if very rich) subsampled to the same fraction, and sorted.

3.5 **Identification**

Botanical identification (to plant family, genus or species level) of the material was carried out with the help of reference material and identification criteria from various sources. Modern fresh and experimentally charred crop reference material was provided by Dr Amy Bogaard, Dr Mike Charles and Dr Mark Nesbitt. Also, for the identification of crop types, criteria provided by Jones *et al*. 2000b, Kohler-Schneider 2003 and Jacomet 2006 were mainly used, combined with observations offered by Charles *et al*. (2010) for differentiating the rachis of two- versus six-row hulled and naked barley (*Hordeum vulgare* L. convar. *distichon*, *H. vulgare* L. convar. *vulgare*). Simplified names of crop identification categories were used following nomenclature from previous Çatalhöyük archaeobotanical reports (Fairbairn *et al*. 2002, 2005a) for the sake of consistency. Intermediate and 'cf.' identification categories (for both crops and wild taxa) encompass remains which do not correspond to all identification criteria due to poor preservation/distortion, or appear to have characteristics of more than one type/species. All large-seeded legumes, including chickpea (*Cicer arietinum* L.) and grass pea (*Lathyrus sativus* L./*cicera* L.), were considered cultivated crops. The domesticated status of pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik.) can been argued based on fragments of indehiscent pea pod found in Space 314 in Building 65 (phase South Q; A. Bogaard, pers. comm.) and indehiscent lentil pod from Building 1 (see below), whereas the domestication status of chickpea and grass pea at Çatalhöyük remains ambiguous (Fairbairn *et al*. 2005a). Flax/linseed (*Linum* sp.) was found in only one sample and could not be determined as domesticated due to poor preservation of the seeds - the asymmetrical notch at the proximal end that potentially distinguishes cultivated flax from wild species could not be confirmed (van Zeist and Bakker-Heeres 1975); the seeds were therefore included with the wild taxa.

Precise identification of the wild plant remains was of particular importance for the study, since ecological requirements and growth habits of genera, and sometimes even species within genera, can differ significantly, especially if they represent weed flora which is highly 'sensitive' to varying agricultural practices (Jones 1983: 43). Therefore, considerable time

was devoted to as precise as possible identification of commonly occurring taxa, since these were to form the basis of the analysis; this goal was highly challenging due to the outstanding diversity of Çatalhöyük wild flora also noted in previous work (Fairbairn *et al*. 2002, 2005a).

Unknown wild taxa were initially given provisional genus/species (sometimes descriptive) names; the specimens were subsequently re-examined and compared alongside each other to check their broad categorisation, and grouped accordingly. For more specific identification, modern seed collections housed in the Institute of Archaeology at Oxford University, Institute of Archaeology at University College London, Department of Archaeology at Sheffield University and British Institute of Archaeology in Ankara were used for comparison with the archaeological specimens. Furthermore, plant sheets in the herbaria of the Royal Botanic Gardens Edinburgh and of the Department of Botany at Selcuk University, Konya were useful references, as well as plants collected by the Çatalhöyük archaeobotany teams in the field (especially the weed collection from einkorn and emmer fields in the province of Kastamonu, North Turkey - see Appendix 1). Previous reports on archaeobotanical remains from Çatalhöyük and other sites in south-west Asia (e.g. van Zeist and Bakker-Heeres 1982, 1984a, 1984b, 1985; van Zeist and Buitenhuis 1983; van Zeist and de Roller 1995), as well as *Flora of Turkey and East Aegean Islands* vol. 1-11 (Davis *et al*. 1965-1988; Güner *et al*. 2001) and other general published and online sources (e.g. Berggren 1969, 1981; Hubbard 1984; Anderberg 1994; Cappers *et al*. 2006; Nesbitt 2006; http://g.willcox.pagesperso-orange.fr) provided valuable guidelines. Finally, the surface-scanning electron microscopy at the Biomedical EM Unit at Sheffield University was used to produce images of modern and archaeological plant specimens of *c*. 50 taxa (of which some are included here, see Ch. 4), aiding the identification by examining the seed coat cell pattern[1].

Nevertheless, species-level identification could only be achieved for a small number of wild taxa since modern reference specimens of the complete range of species in a genus were rarely available, especially in cases where a genus comprises a large number of species (e.g. only ten of the 78 recorded *Gallium* species could be observed across all of the collections). The poor preservation state of some archaeological specimens and, as personally observed

[1] The collection of identified specimens ('wild type collection') is archived at the Institute of Archaeology, Oxford University and is available for consultation in agreement with Dr Bogaard, as are the low- and high-resolution (SEM) images taken by the author. The intention is to collate the images and descriptions of taxa identified at both Neolithic and Chalcolithic Çatalhöyük mounds and present them as an online catalogue.

and confirmed by Dr I. Hedge of the Royal Botanic Garden Edinburgh, the tendency of species of some genera found in Turkey (and elsewhere) to have very similar, morphologically undistinguishable seeds also prevented precise identification of a certain number of taxa. Therefore, wherever possible an attempt was made to at least reduce the number of 'candidates' for a wild plant type to a minimum (e.g. 5) based on the morphological characteristics of the observed modern specimens, and descriptions and illustrations in the literature. The nomenclature for wild taxa follows *Flora of Turkey* (Davis *et al*. 1965-1988).

3.6 Quantification

In order to carry out numerical analysis of the assemblage, quantification of the remains, including standardisation of the MNI (minimum number of items) estimates for certain taxa, was required (Jones 1991). The following sections describe the treatment of the archaeobotanical data, e.g. quantitative description, selection and reduction of the data, in preparation for statistical analysis.

3.6.1 Counting

Absolute counting of the identified items was considered an appropriate method for recording the presence of crop and wild taxa with the aim of determining the botanical composition of individual (or amalgamated) samples assumed to represent distinct deposits resulting from different behavioural events/activities relevant to the research questions (cf. Jones 1991). Fragmented and/or distorted remains were common in the assemblage and it was necessary to ensure that the same plant item was counted only once. A method proposed by Jones (1991: 65-66) for quantification of cereals and wild grasses was adopted, with minor adjustments. Both the apical and embryo ends of cereal grains and grass seeds were counted, but only the greater of the two scores was included in the total number of the seeds. Two halves of cereal grains, split along the furrow were counted as one grain. Glume bases representing chaff of hulled wheats, and rachis internodes of free-threshing cereals and barley, were individually recorded (e.g. hulled wheat spikelet fork was counted as two); terminal spikelets, normally containing one seed, were counted as one. Two halves of free-threshing cereals or barley rachis internodes split lengthwise were counted as one. The very rare finds of basal rachis

internodes representing the insertion point of the rachis into the cereal stem were recorded but not included in cereal chaff counts unless they had visible glume attachments at the top and could be identified as hulled wheat glume bases or free-threshing rachis. The 'embryo end' (radicle) of pulse seeds was counted wherever present and, where absent, the number of pulse seeds was estimated from the fragments; two cotyledons were counted as one pulse seed.

All charred and mineralised identifiable seeds of wild taxa were counted, both whole and fragmented (when fragments of seed of the same taxa did not correspond, i.e. represented separate seeds), as well as indeterminate remains. In cases where the inner seed ('core') was separated from the outer shell (coat/testa), only one of the two parts was counted, depending on their presence (e.g. in *Polygonaceae* often the coat and core occurred separately). Fragmented wild seeds were recorded based on presence/observation of some distinctive features, for example the long embryo in crucifers, the reticulate surface of *Caryophyllaceae*, the distinctive position of embryo in *Polygonum* versus *Rumex* and in laterally (e.g. *Sporobolus, Crypsis*) versus dorsally compressed grass seeds (e.g. *Aeluropus*). Culm nodes and bases representing grass stem (mainly reed) and rhizomes were counted; in case of broken culm nodes, eight fragments were counted as one whole. Reed culm nodes were included in the total taxa per sample count.

In samples rich in *Descurainia* seeds, the seeds were often fused together and impossible to count without damaging them; therefore, the number of seeds was estimated from their volume - i.e. the number of (non-fused) *Descurainia* seeds in 0.1 ml was counted (500) and extrapolated to quantify the 'lumps' of fused seeds. A similar method was applied to lentils in the lentil-rich samples in order to speed up counting – 10 ml contained *c.* 800 lentil seeds. The number of seeds in whole *Juncus* fruits discovered in two samples was roughly estimated based on the visible row of seeds in one of the observed fruit loculi.

For the fruit/nut/tuber category, the estimated number of whole items based on the number/volume of fragments was also used (see Ch. 4). Thus, based on the volume of *c.* 1 ml for a medium-sized complete *Bolboschoenus* tuber, 1 ml of parenchyma was converted to a count of one tuber. The fruit/nut kernel fragments are assumed to belong to one of the identified fruit/nut taxa (*Prunus, Amygdalus, Pistacia* and *Quercus*) and the approximate volume of 1 ml of almond core was taken as an average for conversion of fruit/nut volume into MNI counts because almond is larger than pistachio and *Prunus* seed but smaller than

acorn; therefore, 1 ml of fragmented nut kernels ('fruit/nut meat') was scored as 1 fruit/nut core. Nut hilum (hilar scar on the shell) deriving from individual nut kernels was counted wherever present; otherwise, 20 fragments of almond or acorn shell (or stone in case of *Prunus*) and 15 pistachio shell fragments were converted to 1 whole nut (or fruit). The total number of fruit/nut/tuber taxa per sample therefore represents the sum of following: for nuts - the count of hilum/nutshell or nut cores, whichever greater; for fruit (*Prunus*) - the count of stone/stone fragments; for tuber - the count of whole items and/or converted parenchyma volume. In one sample fragments of acorn cupula were discovered and included (as 1 acorn) since no other acorn remains were present in the sample.

Fragments of pulse (probably lentil) pod and stalk, as well as parts of *Rumex* stalk and tubercle, were discovered in a few samples and counted, but not included in the final counts of items per taxa/sample, and neither were remains such as *Atriplex* bracts, *Medicago* and *Suaeda* seed pods, mineralised cereal awns etc, since the taxa in question were already included in the count based on their seeds present in the same samples. Seeds embedded in dung or with adhering dung, were identified, counted and included as such in totals for the respective taxa/samples.

Complete (sheep/goat) dung pellets were counted, as well as fragments of dung which were in all cases scored as one (no volume to count conversion was attempted); mouse pellets and insect remains were also counted; these non-plant remains, together with indeterminate categories of wild seeds and other plant parts were not included in the total item count. The volume of wood charcoal (extracted from >2 mm fraction of flot and heavy residue) was measured.

3.6.2 **Calculating the total number of items per sample**

The total number of items of each taxon per sample was calculated by adding together the scores from all sorted fractions (4 mm, 2 mm, 1 mm and 0.3 mm) of flots and heavy residue. Where sieve-size fractions were subsampled, the item scores were multiplied up (or divided) by the subsample factor used for 1 mm fraction of the flot. For example, where 1/4 of the 1 mm flot fraction was sorted, counts from the sorted portion of 0.3 mm fraction (minimally 1/32) were multiplied by four, counts for the entirely sorted 4 mm fraction of flot or heavy residue were divided by four etc; thus, in this case, the final counts potentially represent

quarter of the total number of items in the sample. Since this method may introduce some inaccuracies in the total counts of items per sample, the extent of the potential errors was tested on 1 mm and 0.3 mm fractions of a few samples by successively sorting small portions of 0.3 mm (e.g. 1/32) and 1 mm fractions (e.g. 1/4) and counting items in each of them; comparison of the item scores among the respective portions revealed only slight differences and, therefore, any inaccuracies were assumed to be minor. On the other hand, subsampling and multiplying-up significantly reduced the amount of time spent on sorting individual samples, enabling the examination of a larger number of samples. Table 3.4 shows the fractions of the selected samples for which the total item counts were calculated.

Fraction to which original item counts multiplied	Number of samples
1/1	64
1/2	22
1/4	6
1/8	2
total	*94*

Table 3.4 Fractions of the selected samples for which the item counts were calculated

3.6.3 **Amalgamation of taxa**

Before conducting statistical analysis, the long list of over 300 crop and wild taxa was reduced in order to avoid an effect on the analysis of variation between definite and cf. identifications of the same type due to differences in preservation of the material (cf. Colledge 2001; Bogaard 2004a; Valamoti 2004; Hald 2008). Table 3.5 shows the initial and amalgamated crop categories; the amalgamation reduced the number of crop categories to 34 (and the number of wild categories to 104 - see Table 4.4). The cereal taxa were further amalgamated into five types (einkorn, emmer, 'new type' wheat, free-threshing wheat and naked barley), each including grain and chaff categories; indeterminate grain/seed and chaff were grouped into five separate categories (Table 3.6). The absolute counts and proportions of the ten crop (five cereal types and five pulse taxa) and 104 wild taxa formed the basis of numerical/descriptive (Ch. 4) and statistical (Ch. 5, 6) analysis. The taxa were further amalgamated into larger groups as required by some forms of analysis; for example, hulled wheat taxa (einkorn, emmer and 'new type' wheat) were considered together within the hulled wheat group, free-threshing wheat and barley formed the free-threshing cereal group, fruit, nut and tuber were combined into the fruit/nut/tuber group, remaining wild taxa constituted the wild/weed group etc (for more details see Ch. 4).

Initial crop categories	Amalgamated crop categories
CEREAL GRAIN	
cf. *Triticum boeticum*, 1-seeded	*Triticum monococcum*, 1-seeded
Triticum boeticum type, 1-seeded	
T. monococcum/boeticum, 1-seeded	
Triticum monococcum, 1-seeded	
cf. *Triticum monococcum*, 1-seeded	
Triticum monococcum, 2-seeded	*Triticum monococcum*, 2-seeded
cf. *Triticum monococcum*, 2-seeded	
cf. *T. monococcum*, 2-seeded; germinated embryo	
Triticum monococcum, indeterminate	*Triticum monococcum*
cf. *T. monococcum*, indeterminate	
Triticum dicoccum	*Triticum dicoccum*
Triticum dicoccum; germinated embryo	
cf. *Triticum dicoccum*	
cf. *Triticum dicocccum*, 1-seeded	cf. *Triticum dicoccum*, 1-seeded
cf. 'New type' wheat	'New type' wheat
'New type' wheat	
Triticum monococcum/dicoccum	Hulled wheat grain (*T. monococcum*/*dicoccum*/'new type')
T. monococcum/dicoccum, fused	
T. monococcum/dicoccum; germinated embryo	
Triticum dicoccum/'New type' wheat	
Hulled wheat grain, indeterminate	
Free-threshing wheat	Free-threshing wheat (*Triticum aestivum*)
cf. Free-threshing wheat	
Barley, naked, straight grain	Naked barley grain
Barley, naked, twisted grain	
cf. Barley, naked, twisted grain	
Barley, naked	
cf. Barley, naked	
Barley grain, indeterminate	Barley grain
Triticum indeterminate (sp.)	Wheat grain, indeterminate
T. dicoccum/Free threshing wheat	
Triticum/Hordeum	Wheat/barley grain, indeterminate
Cerealia indeterminata	Cereal grain, indeterminate
CEREAL CHAFF	
Triticum sp., terminal glume bases	Hulled wheat, terminal glume bases
Triticum boeticum type	*Triticum monococcum*, glume bases
cf. *Triticum boeticum*	
Triticum monococcum/boeticum	
Triticum monococcum	
Triticum dicoccum	*Triticum dicoccum*, glume bases
'New type' wheat, glume bases	'New type' wheat, glume bases
T. dicoccum/'New type' wheat, glume bases	*T. dicoccum*/'New type' wheat, glume bases
T. dicoccum/'New type' wheat, basal glume bases	
Hulled wheat, indeterminate glume bases	Hulled wheat, glume bases
Triticum aestivum type, rachis	*Triticum aestivum*, rachis
Triticum aestivum/durum type, rachis	
T. aestivum/durum type, basal rachis	

Table 3.5 The initial and amalgamated (final) crop identifications

Initial crop categories	Amalgamated crop categories
Naked barley, basal rachis, 6-row	Naked barley, rachis, 6-row
Naked barley, rachis, 6-row	
Naked barley, rachis, 2-row	Naked barley, rachis, 2-row
Naked barley, basal rachis, 2-row	
Barley, indeterminate rachis	Barley, indeterminate rachis
Barley, indeterminate basal rachis	
cf. wild *Triticum* sp. glume bases	Indeterminate chaff
chaff, indeterminate	
basal rachis internode/top culm section	
Cereal type culm node	Cereal type culm node
mineralised awns	mineralised awns
PULSES	
Lentil (*Lens culinaris*)	Lentil (*Lens culinaris*)
cf. Lentil (*Lens culinaris)*	
Lentils within testa	
Pea (*Pisum sativum*)	Pea (*Pisum sativum*)
cf. Pea	
Chickpea (*Cicer arietinum*?)	Chickpea (*Cicer arietinum*?)
Bitter vetch (*Vicia ervilia*)	Bitter vetch (*Vicia ervilia*)
cf. *Vicia ervilia*	
Grass pea (*Lathyrus sativus/cicera*)	Grass pea (*Lathyrus sativus/cicera*)
cf. Grass pea (*Lathyrus sativus/cicera*)	
large pulse indeterminate	Large pulses, indeterminate
Lentil stalks	Lentil stalks
cf. pulse (lentil) stalk	
Lentil pod	Lentil pod

Table 3.5 - *continued* The initial and amalgamated (final) crop identifications

The abundance and frequency of the five indeterminate crop categories (see above) were relatively high, thus for certain analytical steps proportionally reassigned data were used (Table 3.7). This was achieved by converting counts of indeterminate crop categories into counts of determinate categories based on proportions of the latter, on a sample by sample basis. The method assumes that the indeterminate crop material is likely composed of the same crop types/groups represented in the more specifically identified crop material; moreover, the proportions of the identified crop types/groups are probably the same in both determinate and indeterminate crop material. For example, the proportion of hulled wheat grain in the indeterminate wheat grain category (*Triticum* sp. grain) is assumed to be the same as the proportion of hulled wheat grain in the overall number of determinate wheat grain items (which includes hulled and free-threshing wheat grain) in a sample. Thus, based on the proportional representation of crop types/groups in the determinate crop material (identified to type/species), the indeterminate crop remains were re-assigned (i.e. added) to the existing

crop types/groups by adjusting ('correcting') their absolute counts across the samples. The procedure was as follows: 1) 'indeterminate wheat grain' was re-assigned to hulled and free-threshing wheat grain; 2) 'indeterminate cereal grain' was distributed across hulled wheat, free-threshing wheat and barley grain; 3) 'indeterminate large-seeded legumes' were allocated to the five identified pulse types. The 'old' and 'new' total counts for the crop types/groups are presented in Table 3.7.

Amalgamated crop categories	**Crop types**	Groups
CEREALS		
Triticum monococcum, 1-seeded	EINKORN	Hulled wheats
Triticum monococcum, 2-seeded		
Triticum monococcum		
Triticum monococcum, glume bases		
Triticum dicoccum	EMMER	
cf. *Triticum dicoccum*, 1-seeded		
Triticum dicoccum, glume bases		
'New type' wheat	'NEW TYPE' WHEAT	
'New type' wheat, glume bases		
Free-threshing wheat (*Triticum aestivum*)	FREE-THRESHING WHEAT	Free-threshing cereals
Triticum aestivum, rachis		
Naked barley grain	NAKED BARLEY	
Barley grain		
Naked barley, rachis, 6-row		
Naked barley, rachis, 2-row		
Barley, indeterminate rachis		
PULSES		
Lentil (*Lens culinaris*)	LENTIL	Pulses
Pea (*Pisum sativum*)	PEA	
Chickpea (*Cicer arietinum*?)	CHICKPEA	
Bitter vetch (*Vicia ervilia*)	BITTER VETCH	
Grass pea (*Lathyrus sativus/cicera*)	GRASS PEA	
INDETERMINATE		
Hulled wheat grain	HULLED WHEAT GRAIN	Hulled wheats
T. dicoccum/'New type' wheat, glume bases	HULLED WHEAT GLUME BASES	
Hulled wheat, terminal glume bases		
Hulled wheat, indeterminate glume bases		
Wheat grain, indeterminate	INDETERMINATE WHEAT GRAIN	
Wheat/barley grain, indeterminate		
Cereal grain, indeterminate	INDETERMINATE CEREAL GRAIN	
Large pulses, indeterminate	INDETERMINATE LARGE PULSE	
Indeterminate chaff	*excluded*	
Cereal type culm node	*excluded*	
mineralised awns	*excluded*	
Lentil stalks	*excluded*	
Lentil pod	*excluded*	

Table 3.6 The amalgamated (determinate and indeterminate) crop types

The category 'indeterminate chaff' was disregarded as it was impossible to determine whether it derived from cereals or wild grasses due to poor preservation. In order to investigate whether proportional re-assignment affects the results of multivariate statistical analysis, the discriminant and correspondence analysis were carried out using 'old' and 'new' item counts. No major differences between the results using the two datasets were detected; therefore, the crop total values that include proportionally re-assigned indeterminate crop categories were used in the analysis (Ch. 5-6).

DATA PRIOR TO PROPORTIONAL RE-ASSIGNMENT				
	Abundance		Ubiquity	
Indeterminate crop category	count		count	%
Indeterminate wheat grain	955		87	92.55
Indeterminate cereal grain	4344		93	98.94
Indeterminate large pulse	483		86	91.49
Cereal types	'old' counts	%	Ubiquity	
Hulled wheat grain	2388	68.94	93	98.94
Free-threshing wheat grain	121	3.49	26	27.66
Barley grain	955	27.57	66	70.21
total determinate grain	*3464*	*100.00*		
PROPORTIONAL RE-ASSIGNMENT				
***Step 1**) Proportional re-assignment of indeterminate wheat grain to wheat types*				
	'old' counts	%	Step 1) counts	%
Hulled wheat grain	2388	95.18	3297	95.18
Free-threshing wheat grain	121	4.82	167	4.82
total wheat grain	*2509*	*100.00*	*3464*	*100.00*
***Step 2)** Proportional re-assignment of indeterminate cereal grain to cereal types*				
	'old' counts	%	'new' counts	%
Hulled wheat grain	3297*****	74.61	**6538**	74.61
Free-threshing wheat grain	167*****	3.78	**331**	3.78
Barley grain	955	21.61	**1894**	21.61
total cereal grain	*955*	*100.00*	***8763***	*100.00*
	******* *'old' = the Step 1) count*			
***Step 3)** Proportional re-assignment of indeterminate large-seeded pulse to pulse types*				
	'old' counts	%	'new' counts	%
Lentil	44717	98.61	**45193**	98.61
Pea	239	0.53	**242**	0.53
Chickpea	9	0.02	**9**	0.02
Bitter vetch	377	0.83	**381**	0.83
Grass pea	5	0.01	**5**	0.01
total pulse	*45347*	*100.00*	***45830***	*100.00*

Table 3.7 Proportional re-assignment of indeterminate crop grain/seed

3.6.4 **Amalgamation of samples**

In order to ensure that the samples included in further analysis represent individual 'behavioural episodes' (Jones 1991: 67) and not multiple sampling of deposits resulting from the same event/activity (which can obscure or amplify any patterns in the assemblage), samples originating from the same excavation unit were compared in terms of their botanical density and composition, and the potential for their amalgamation was assessed (cf. Bogaard 2004a; Valamoti 2004; Hald 2008). Out of the total of 92 excavation units selected for analysis, 16 were represented by two or more samples. Density was calculated by dividing the total number of plant items by the number of litres of soil floated for each sample. On the basis of clear justification from the archaeological stratigraphy, and on the grounds of similar botanical density and composition (the range and abundance of taxa), sample pairs or groups in 13 units were amalgamated (Table 3.8). In two units samples appeared to represent distinct layers within the deposits, and their density and composition differed significantly; they were therefore treated as separate samples. In another unit, two samples derived from the same deposit (fill of a fire installation), but one of them was dominated by seeds of a single taxon (*Descurainia sophia*), while another was more mixed in composition (likely contaminated by surrounding deposit) and so the latter was excluded from further consideration. The amalgamation resulted in the final 94 samples (out of the 115 selected) entered in the analysis.

3.7 Statistical data analysis

3.7.1 **Discriminant analysis**

In the present study, discriminant analysis was used as a method for direct comparison of the archaeobotanical 'weed' data with data from modern weed studies. Discriminant functions that were extracted to maximise separation among modern 'known' (pre-defined) groups of samples/taxa were used to classify archaeobotanical ('unknown') samples (cf. Jones 1987; Jones *et al*. 2000a; Bogaard *et al*. 2001; Bogaard 2004a; Charles and Bogaard 2001, 2010). Application of the method developed by Jones (1984, 1987) enabled identification of crop processing stages represented in the Çatalhöyük archaeobotanical samples by using the same discriminant functions that distinguished between modern (ethnographic) crop processing

Sample number	Unit number	Building	Space	Context type	Total items	Density (total items/ soil volume)	Sample fraction
74	1246	1	71	building fill	310	16	1/1
103	1246	1	71	building fill	1099	42	1/1
74+103 amalgamated					*1409*	*31*	*1/1*
171	1314	1	71	bin fill	546	21	1/1
329	1314	1	71	bin fill	329	14	1/1
171+329 amalgamated					*875*	*18*	*1/1*
539	1455	1	186	building fill	911	202	1/8
551	1455	1	186	building fill	496	99	1/8
539+551 amalgamated					*1407*	*148*	*1/8*
1297	2845		115	external midden	950	33	1/1
1640	2845		115	external midden	774	24	1/1
1297+1640 amalgamated					*1724*	*28*	*1/1*
2594	4540	18	171	rake-out	267	11	1/1
2595	4540	18	171	rake-out	345	12	1/1
2596	4540	18	171	rake-out	333	14	1/1
2594+2595+2596 amalgamated					*945*	*12*	*1/1*
2625	4548	18	171	rake-out	295	8	1/1
2636	4548	18	171	rake-out	144	8	1/1
2625+2636 amalgamated					*439*	*8*	*1/1*
2637	4557	18	171	floor occupation	154	5	1/1
2638	4557	18	171	floor occupation	295	10	1/1
2637+2638 amalgamated					*449*	*7*	*1/1*
2713	4664	18	172	bin fill	647	36	1/1
2715	4664	18	172	bin fill	421	20	1/1
2713+2715 amalgamated					*1068*	*27*	*1/1*
3104	4517		199	penning	457	18	1/1
3106	4517		199	penning	579	17	1/1
3107	4517		199	penning	650	22	1/1
3104+3106+3107 amalgamated					*1686*	*19*	*1/1*
3127	4866		181	external midden	1413*****	94	1/2
3133	4866		181	external midden	645*****	43	1/2
3137	4866		181	ash deposit in external midden	2117	255	1/4
3127+3133+3137 amalgamated					*3167*	*136*	*1/4*
3148	4869		181	external midden (burning event)	962	153	1/4
3149	4869		181	external midden (burning event)	921	111	1/4
3151	4869		181	external midden (burning event)	1577*****	99	1/2
3148+3149+3151 amalgamated					*2688*	*119*	*1/4*
1631	2238	3	86	roof collapse	416*****	139	1/1
1649	2238	3	86	roof collapse	1164*****	90	1/1
1664	2238	3	86	roof collapse	1274*****	80	1/1
1732	2238	3	86	roof collapse	1668	83	1/2
1631+1649+1664+1732 amalgamated					*3110*	*86*	*1/2*
4545	8178		85	external midden	1285	428	1/4
4626	8178		85	external midden	1370	489	1/4
4545+4626 amalgamated					*2655*	*458*	*1/4*

***** divided by 2 to adjust sample fractions

Table 3.8 Amalgamation of samples derived from the same unit

groups on the basis of their weed type composition. The weed types were established based on the physical properties of weed seeds relevant to the main crop processing stages (i.e. winnowing, coarse sieving, fine sieving - see Section 5.2.1.2), as determined in the ethnoarchaeological study of crop processing sequence on the island of Amorgos, Greece (Jones 1984, 1987). The discriminant analysis was performed using SPSS for Windows (Norusis 2002); the results are presented and discussed in Section 5.3.2.

Discriminant analysis was also used to explore the intensity of crop cultivation at Çatalhöyük (Section 7.3.4). The discriminant functions previously obtained from a modern weed study of intensive and extensive husbandry practices in Evvia, Greece proved useful in assessing intensity levels of crop cultivation in a second modern study in Asturias, Spain, and have subsequently been applied to archaeobotanical weed assemblages (Jones *et al*. 1999, 2000a, Bogaard *et al*. 2001; Charles *et al*. 2002; Bogaard 2004a). The analysis was based on a functional plant ecological approach (see below) to present-day weed floras recorded in pulse plots in and around a group of villages in central Evvia, which were managed with variable intensity, providing a basis for examination of Çatalhöyük cultivation intensity and scale by comparing the two datasets using discriminant analysis. The archaeobotanical weed taxa were characterised using six functional plant attributes relevant to crop cultivation intensity, for which data are maintained in a FIBS database at the Department of Archaeology, University of Sheffield: flowering period, canopy height, canopy spread, specific leaf area, the ratio of leaf area per node and leaf thickness, and amphistomaty. Since the weed data in the modern (Greek) and the present study were recorded in different ways (presence in survey quadrats versus seed counts per sample, respectively), they were in both cases simplified to the semi-quantitative (presence/absence) level to enhance their comparability (cf. Charles *et al*. 2002; Bogaard 2004a). Mean attribute scores were calculated for each archaeobotanical and modern unit of analysis (samples and quadrats, respectively) by adding up attribute values for the taxa present and dividing them by the total number of taxa; these attribute scores were used as discriminating variables in the discriminant analysis. The results of the analysis and their implications for understanding Çatalhöyük crop husbandry are discussed in Section 7.3.

3.7.2 **Correspondence analysis**

Correspondence analysis is a multivariate exploratory technique increasingly used in archaeobotany as a method of investigating variation among the samples in terms of their

botanical composition, with the aim of identifying and interpreting major trends in the dataset (e.g. Lange 1990; Shennan 1997; Colledge 2001; Baxter 2003; Bogaard 2004a). In this study it was applied to the combined crop and wild assemblage, as well as to data for the wild taxa only, in order to explore major trends and, in particular, variation potentially resulting from differences in the major sources of the material, i.e. crop processing and burning of animal dung (Ch. 6).

Correspondence analysis arranges units of analysis (here, samples) along four axes based on the combination and abundance of the variables (here, botanical taxa/categories), that is, according to the similarities and differences in the composition of the samples; it does this by comparing the composition of each sample with every other sample (Lange 1990; Shennan 1997; Bogaard 2004a). In the resulting scatter plots, the distribution of sample data points reveals trends in the variation of the sample composition. The point where the axes meet (the 'origin') is neutral, meaning that the samples in this zone have an 'average' composition (e.g., dominated by ubiquitous taxa); divergence from this 'standard' composition results in the samples being distanced from the origin to a certain degree and in a specific direction. The distance between (groups of) samples indicates the level of their compositional similarity - the closer they are, the greater the similarity. For example, the samples concentrated at one end of an axis are of similar composition, which is different to that of the samples at the origin, and of the samples (if any) at/towards the opposite end of the axis. The axis, therefore, reflects a trend of variation among samples. Correspondence analysis also reveals relationships among taxa based on their arrangement along the axes. For instance, species at the origin are common across the assemblage, whereas those at some distance from the origin tend to occur in a limited number of samples. Moreover, comparison of species plots and sample plots illustrates their (dis)association based on similarities in their distribution, i.e. divergence from the origin in the same or opposite directions (Bogaard 2004a: 93).

The statistical computer package Canoco for Windows 4.5 (ter Braak and Smilauer 1997-1999) was used to run the analysis, and CanoDraw for Windows (Smilauer 1992) to plot results graphically. Most of the variation was usually borne out on the first two axes (which by definition account for the most variation in the data - cf. Shennan 1997: 318) and they are the ones shown in the plots: axis 1 horizontally and axis 2 vertically. In the process of examining possible causes of variation, a range of sample classifications (e.g. context type, chronological phase) and species categories (e.g. based on their biology and ecology) were

displayed in the plots using different symbols for the data points. Pie-charts based on seed counts of taxa within different crop and wild categories were also used to illustrate trends in the sample composition.

3.8 The use of ecological (and biological) data

A range of ecological (and biological) characteristics of the wild taxa were collected and examined as part of the analysis of animal diet and crop husbandry practices. *The Flora of Turkey* (Davis *et al*. 1965-1988; Güner *et al*. 2001) was the main source of information on growing conditions and habitat, vegetation formations, life cycle, flowering time (onset and duration), stem height and morphology and, where available, descriptions of plant structure and other characteristics indicating potential palatability/accessibility to animals. Data and observations on some other aspects, such as ecological specialisation and plant strategy, for example, were extracted from other appropriate literature (e.g. Ellenberg 1950, 1988; Dallwitz 1980; Grime 1979, 2002; Grime *et al*. 1988, 1990; van Soest 1987; Dallwitz *et al*. 1993; Gardener *et al*. 1993).

For the investigation of intensity of crop cultivation at Çatalhöyük the functional ecological approach was applied, based on the FIBS (Functional Interpretation of Botanical Surveys) methodology developed at the Unit of Comparative Plant Ecology, University of Sheffield (Hodgson 1991; Charles *et al*. 1997; Bogaard *et al*. 1999, 2000, 2001; Jones *et al*. 2000a; Jones 2002, 2010). In general, the method uses measurements of certain plant functional attributes (i.e. morphological and behavioural traits), which are indicators of species' potential in response to specific ecological gradients (such as fertility, soil disturbance and moisture), for ecological interpretation of archaeobotanical weed data. Application of this approach in archaeobotany has been demonstrated through a number of studies in Europe and Western Asia; it has been shown that FIBS is particularly suited for comparisons of modern and ancient weed assemblages and for distinguishing between ecological factors relevant to different models of past crop husbandry practice (Hoppé 1999; Charles *et al*. 2002; Charles and Hoppé 2003; Charles *et al*. 2003; Bogaard 2004a).

A functional ecological investigation of present-day weed floras associated with different scales of cultivation on the island of Evvia in Greece found that the functional attributes

related to soil fertility and disturbance are the most useful for distinguishing between intensive (garden) and extensive (field) crop cultivation (Jones *et al*. 2000a; Bogaard *et al*. 2001). It was demonstrated that soil fertility, which in gardens is improved by manuring and watering, affects the duration and quality of weed growth period, and can be explored using measurements of three relevant functional attributes: canopy height and diameter, leaf size (leaf area per node:leaf thickness) and specific leaf area (leaf area:dry leaf weight). High levels of soil disturbance through hoeing and weeding of gardens at sowing time and/or during growing season is reflected in the ability of weeds to regenerate under these conditions (e.g. vegetatively from root fragments) and can be measured using another three relevant functional attributes: length of the flowering period, vegetative spread, and stomatal distribution (for detailed descriptions of the attributes see e.g. Charles *et al*. 1997; Bogaard 2004a). A set of six functional attributes (specific leaf area; flowering period; canopy height; canopy spread; leaf area per node: leaf thickness; amphistomaty) successfully discriminated between the observed intensively cultivated gardens and extensively cultivated fields in Greece, and these were therefore used as discriminating variables in this study (see above). The relevance of modern functional attribute measurements to Neolithic weed assemblages may be problematic, given that weed ecology is unlikely to have remained stable over time. However, the use of *suites* of attributes and multiple weed taxa reduces any potential effect on the comparability of the two datasets, since it is unlikely that all species would have changed in the same way(s) (e.g. Hoppé 1999; Jones 1992, 2002; Charles *et al*. 2003; Bogaard 2004a).

Chapter 4 Overview of the assemblage

This chapter explores major compositional aspects of the archaeobotanical samples using quantitative and qualitative approaches. The relative abundance of major categories of botanical material is here used as a basis for classification of the samples into groups. These broad groupings provide a simplified overview of botanical composition and aid consideration of the effects of formation processes relevant to the assemblage (Ch. 5). A finer-grained analysis of botanical composition and assessment of variability among and within major sample groups is presented in Chapter 6.

4.1 Preservation

Macroscopic archaeobotanical remains on archaeological sites are most commonly preserved through carbonization or charring, waterlogging, mineralization and desiccation (e.g. Renfrew 1973; Green 1982; Jacomet and Kreuz 1999; Pearsall 2000). Previous work at Çatalhöyük has revealed three modes of preservation of macro-botanical remains: charring, mineralisation and silicification/calcification (Asouti *et al*. 1999; Fairbairn *et al*. 2002, 2005a; Matthews 2005a). The samples included in the present study contain remains in all of these preservation states.

Remains of plants charred in fires constitute the most commonly preserved plant remains at Çatalhöyük (Fairbairn *et al*. 2005a: 140); they also dominate the samples selected for the present study. Mineralised plant parts are preserved through replacement of the original plant tissues by minerals (carbonates and phosphates) from the local environment, and are common in middens, latrines and cesspits, where high levels of mineral salts are present (Green 1979; Jacomet and Kreuz 1999; Fairbairn *et al*. 2005a). At Çatalhöyük, mineralised seeds were previously recovered from midden and penning contexts where animal dung was viewed as their most likely source (Fairbairn *et al*. 2005a); within the present study, a small number of mineralised club-rush (*Bolboschoenus glaucus* (Lam.) S.G. Smith) seeds were also encountered in the same context types. Silicification/calcification refers to natural accumulation of minerals in cells during plant growth and is common in monocotyledons (e.g. grasses), but also other plant groups (Piperno 2006: 41). In previously analysed material from Çatalhöyük a number of remains preserved in this way were noted (Fairbairn *et al*.

1999, 2005a); they also occur in the samples in this study and include calcareous hackberry fruit stones (*Celtis* L.), and siliceous *Boraginaceae* seeds, spikerush seeds (*Eleocharis* R. Br.) and duckweed seeds (*Lemna* L.).

4.2 General sample composition

Full archaeobotanical analysis revealed that all of the selected samples exceeded the criteria for minimal richness in crop and/or wild plant remains (Section 3.3). Specifically, each sample contained at least 100 crop plus at least 30 wild plant remains, or a minimum of 100 wild plant remains. Ninety-one out of the 94 selected samples (97%) met the '100 crop+30 wild' criterion; the remaining three samples were poor in crop remains but met the '100 wild' criterion. After sorting of whole samples or sufficient random subsamples, the majority were represented by at least 400 identified crop items (53 out of 94 or 56%), while all were represented by at least 30 identified wild items; each of the three samples poor in crop were found to contain at least 400 identified wild items. Absolute counts of crop and wild items, after any necessary multiplication of the subsamples sorted, are shown in Table 4.1; percentages of crop and wild material per sample are illustrated in Figure 4.1.

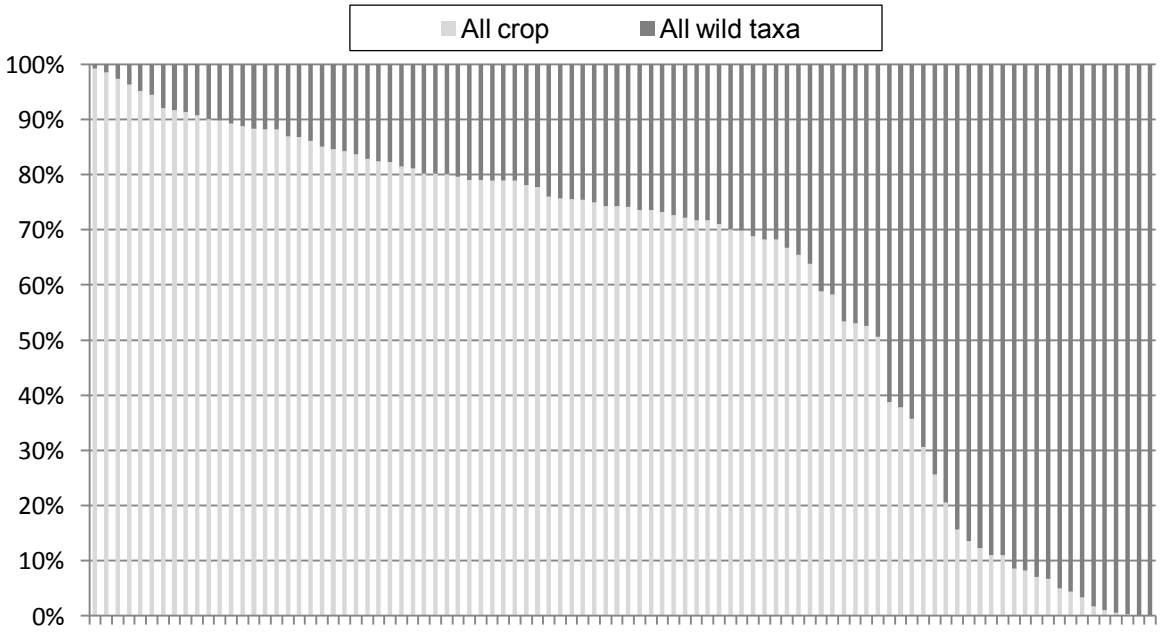


Figure 4.1 Proportions of crop and wild material across the samples

Both absolute counts and percentages show that the majority of samples are dominated by crop remains. Using an arbitrary cut-off of 70% of either crop or wild content, 58 out of 94 samples could be characterised as crop-rich, 20 as wild-rich and the remaining 16 samples as 'intermediate' or 'mixed' (Table 4.1). If a lower arbitrary cut-off is applied - e.g. 60% - then 64 samples could be considered crop-rich, 24 could be described as wild-rich, and six samples would be 'mixed' (Table 4.1). The observation that the majority of samples are crop-rich suggests that crop processing analysis is the first necessary step towards understanding the taphonomy of the assemblage. It is anticipated that crop-rich samples in particular will provide crucial information relevant to crop husbandry consideration (Ch. 7). Although the samples dominated by wild plant seeds could also represent by-products of crop processing (e.g. weed seeds removed from the crop product by fine sieving – Jones 1990), other sources of wild plant remains may be relevant here, such as burning of animal dung as fuel or the collection of wild plants for food/fodder and other uses.

4.3 Crops

Ten major crop types were represented in the samples analysed: einkorn (*Triticum monococcum* L.), emmer (*T. dicoccum* Schrank), 'new type' hulled wheat (Jones *et al*. 2000b; Kohler-Schneider 2003), free-threshing wheat (*T. aestivum* L./*durum* Desf.), naked barley (*Hordeum vulgare* L. var. *nudum*), lentil (*Lens culinaris* Medik.), pea (*Pisum sativum* L.), bitter vetch (*Vicia ervilia* (L.) Willd.), chickpea (*Cicer aretinum* L.) and grass pea *(Lathyrus sativus* L./*cicera* L.) (Table 4.2). A commentary on the abundance (number of remains) of each crop type and their ubiquity (number of samples in which they occur) is provided below.

4.3.1 Cereals

Remains of domesticated cereals were found in every sample analysed. The evidence for cereal cultivation comes chiefly from the remains of cereal chaff: hulled wheat spikelet forks and glume bases, and free-threshing cereal rachis segments. According to the abundance and ubiquity of hulled wheat remains in the samples, it can be suggested that hulled wheats were the main crops produced and consumed at the site. However, in archaeobotanical assemblages hulled wheats tend to be overrepresented relative to free-threshing cereals as a consequence of the different post-harvest treatment (pre-storage processing) of hulled wheats

which could have resulted in semi-clean grain (grain in the spikelet) stored for later use and then further processed on a daily etc basis; by-products of day-to-day cleaning could have been thrown into domestic fires and would have had more chance of becoming charred and preserved (Green 1982; Hillman 1981, 1984a; van der Veen 2007).

Crop type	Abundance (number of items)	Ubiquity	
cereals		count	%
EMMER	**8591**	**94**	**100.00**
Emmer grain	158	61	64.89
Emmer glume bases	8433	94	100.00
'NEW TYPE' WHEAT	**1914**	**83**	**88.30**
'New type' wheat grain	8	6	6.38
'New type' wheat glume bases	1906	82	87.23
EINKORN	**1007**	**86**	**91.49**
Einkorn grain	543	80	85.11
Einkorn glume bases	464	65	69.15
FREE-THRESHING WHEAT	**1420**	**90**	**95.74**
Bread wheat grain	121	26	27.66
Bread wheat rachis	1299	87	92.55
NAKED BARLEY	**1334**	**84**	**89.36**
Naked barley grain	955	66	70.21
Naked barley rachis	379	75	79.79
pulses		87	92.55
LENTIL	44717	67	71.28
PEA	239	52	55.32
CHICKPEA	9	7	7.45
BITTER VETCH	377	47	50.00
GRASS PEA	5	1	1.06
indeterminate			
Hulled wheat grain	1679	90	95.74
Hulled wheat glume bases	34212	94	100.00
Indeterminate cereal grain	5299	94	100.00
Indeterminate large-seeded pulses	483	86	91.49

Table 4.2 The overall abundance and frequency (ubiquity) of the ten crop types

Hulled wheats were discovered in crop stores described by Helbaek - he reports finds of einkorn grain, and emmer grain and ‘spikelet parts’ (Helbaek 1964: 122). In the current excavations, evidence of hulled wheat (spikelet) storage was encountered in a burnt Building 77, while their remains (mostly glume bases) have been found charred *in situ* in hearths and rake-outs throughout the period of occupation investigated by the renewed excavation

(Fairbairn *et al.* 2002, 2005a; Bogaard *et al*. 2005a, 2008). A closer look at the data shows that, of the hulled wheats, emmer outnumbers einkorn and 'new type' wheat both in the total number of remains and in the number of occurrences (Table 4.2). The observed dominance of emmer in the analysed samples is consistent with the results obtained in previous work (Helbaek 1964; Fairbairn *et al*. 2002, 2005a). The conspicuous abundance of 'new type' wheat glume bases as opposed to small number of 'new type' wheat grain could (also) be due to the marked difficulty in identifying 'new type' wheat grain (G. Jones, A. Bogaard pers. comm.). One- and two-seeded einkorn was documented through presence of grain of the two einkorn forms (Kreuz and Boenke 2002), showing that both varieties occur in the assemblage.

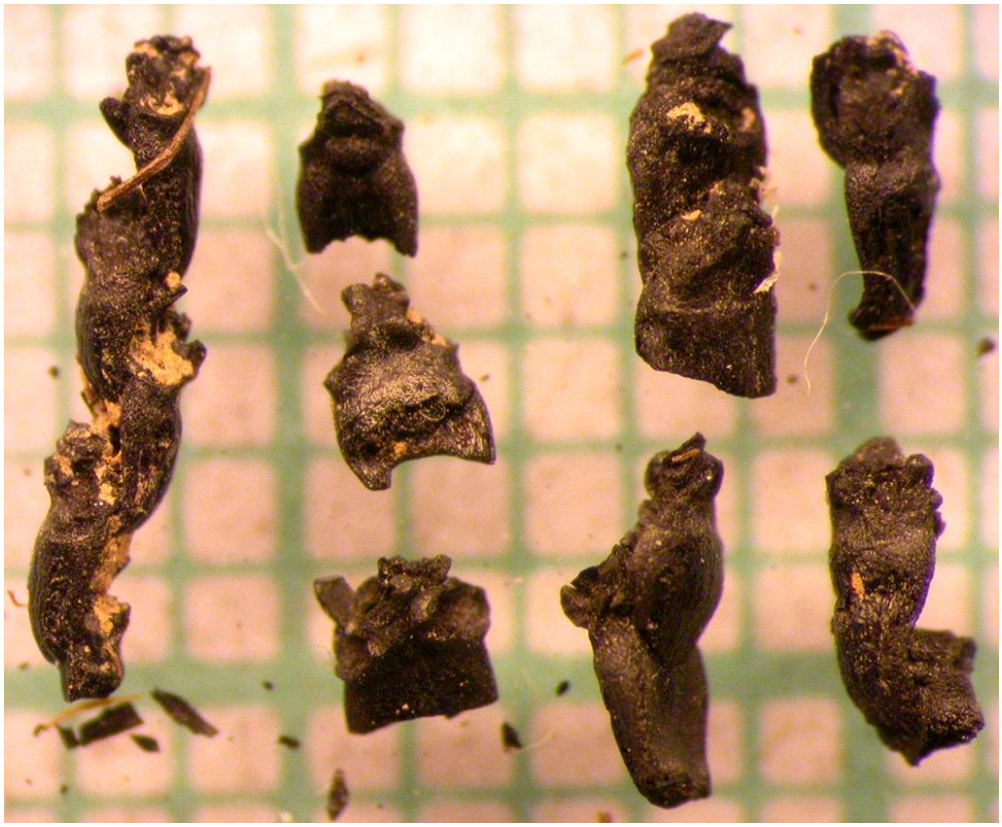


Figure 4.2 Rachis segments of bread wheat (*Triticum aestivum* L.)

Free-threshing wheat and naked barley remains were relatively common in the samples (free-threshing wheat was recorded in 90 samples, barley in 84), and they are also represented by grain and chaff (rachis). According to the morphology of free-threshing wheat rachis segments (Jacomet 2006), which were much more frequent and abundant in the samples than free-threshing wheat grain, the grain and rachis segments were assigned to hexaploid naked wheat (bread wheat, *Triticum aestivum* L.; Fig. 4.2). Rachis segments of six-row (with three

grains per rachis node; *Hordeum vulgare* convar. *vulgare* var. *nudum*) and two-row (single grain in rachis node; *H. vulgare* convar. *distichon* var. *nudum*) naked barley were identified (Fig. 4.3a, b; Charles *et al*. 2010), as well as symmetrical and asymmetrical grains of naked barley forms (asymmetrical grains being characteristic of six-row barley; Jacomet 2006). In contrast to free-threshing wheat, barley grain was much more abundant (but less frequent) than barley rachis. Similar to hulled wheats, the likelihood of preservation of free-threshing cereals could have been influenced by post-harvest processing which, in this case, would have resulted in stored clean grain released from chaff, which would therefore have had less chance of becoming charred in domestic contexts (Hillman 1985). Free-threshing wheat and six-row naked barley were also constantly present in the previously analysed dataset, and were as well less frequent than hulled wheat (Helbaek 1964; Fairbairn *et al.* 2005a).

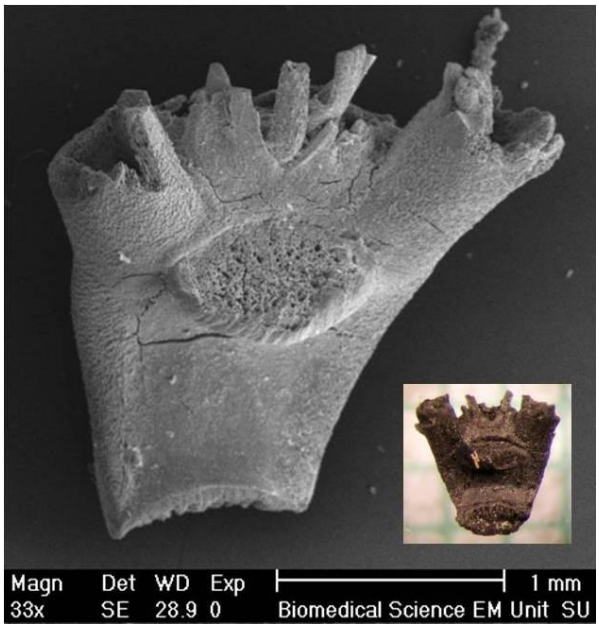


Figure 4.3a Basal rachis segment of six-row naked barley

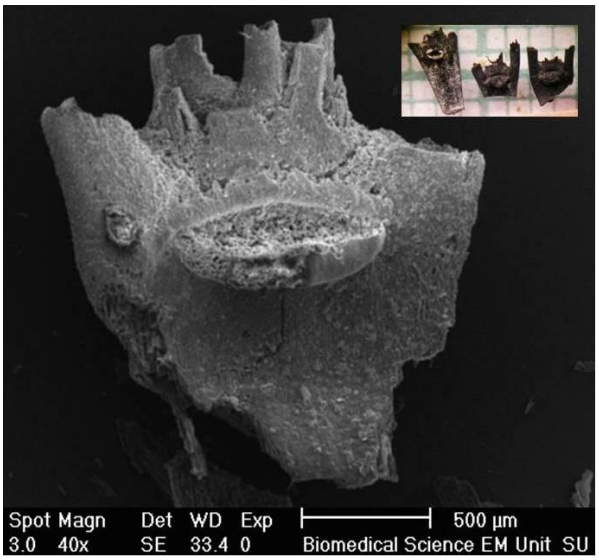


Figure 4.3b Rachis segment of two-row naked barley

4.3.2 **Legumes**

Among the legumes, encountered in 87 out of 94 samples, lentils, peas and bitter vetch stood out in terms of frequency and abundance (Table 4.2); seeds of chickpea and grass pea were also encountered in a few samples in very low numbers. Helbaek (1970) had considered lentils as a weed due to their scarcity across the dataset. In the later archaeobotanical work (Fairbairn *et al*. 2005a), concentrations of pure lentils were found burnt *in situ* in a storage context in Building 1 in the North Area, indicating the crop-status and importance of the

plant. A sample from the same context/feature in the same building was included in the current study and was composed entirely of lentils (Sample 144). Contrary to the Fairbairn *et al.*'s remark that "lentil...in Building 1... [represents] stores of fully processed seed" (2005a: 173; also Hastorf 1996), the present analysis has revealed that the lentil-rich context also contained fragments of pulse pod and pulse pod stalks (pulse 'chaff'; Fig. 4.4a, b). This unambiguously confirms implications from micromorphological analysis of the same context (Matthews 2005a, 2010) and suggests possible evidence of storage of semi-processed lentils. Moreover, the presence of pod remains, including fragments of indehiscent pod still containing lentil seeds, provides unique direct evidence of biological domestication in this pulse crop, equivalent to the non-shattering ear of domesticated cereals (Fuller 2007).

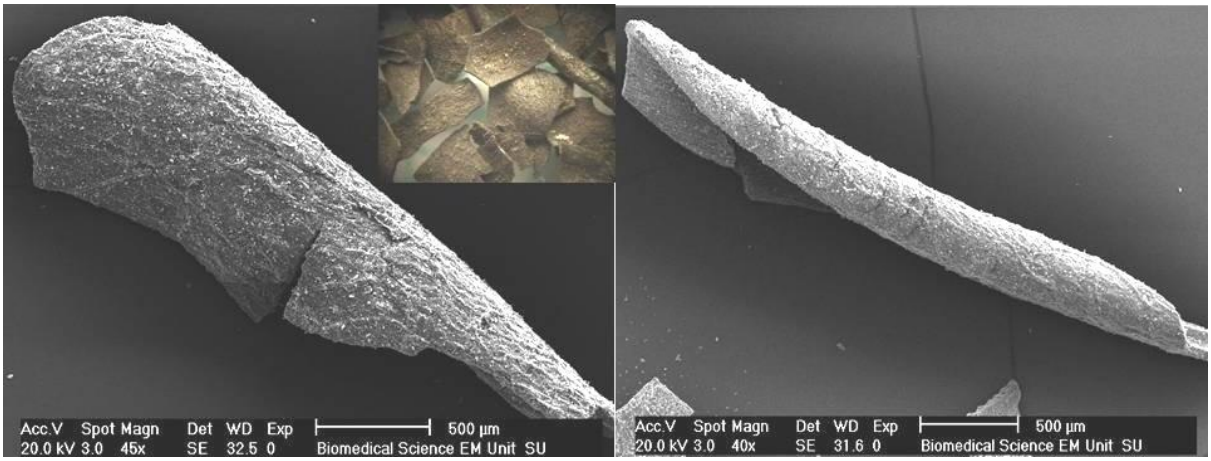


Figure 4.4a Fragments of the lentil pod

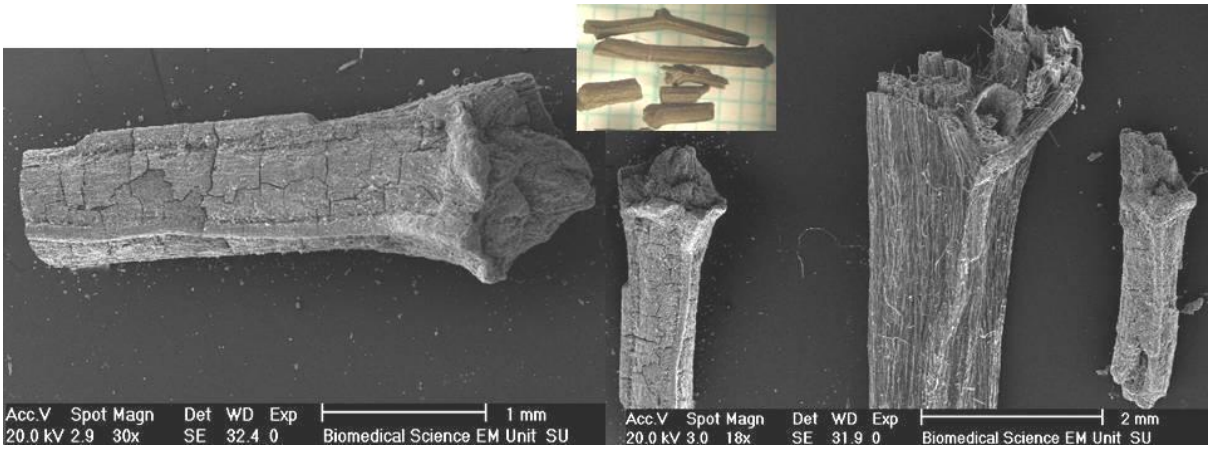


Figure 4.4b Fragments of the lentil stalk

Similar to lentils, pea and bitter vetch occurred in more than half of the selected samples, while their overall quantity was much lower than that of lentils. Both could be considered an

important component of legume-based foods (Butler 1995; Fairbairn *et al*. 2005a) and, according to Helbaek's analysis, *Pisum sativum* was the dominant legume (Helbaek 1964). Recent discoveries at Çatalhöyük include remains of (also indehiscent) pea pod (Fig. 4.5) as evidence of cleaning of peas (and of their domesticated status - Bogaard *et al*. 2008, in press/2013). In the present study, a sample from a 'burnt deposit' in an open space (Space 181) in the South Area contained a significant number of bitter vetch seeds (Sample 3742 with 244 seeds, *c*. 49% of the total number of bitter vetch seeds in the assemblage) perhaps reflecting an activity such as food/fodder preparation or cleaning of a storage area. Due to the necessary removal of toxins from bitter vetch seeds prior to human consumption, the species has often been considered as a human food only in times of famine (Zohary and Hopf 2000). Results of archaeobotanical investigations from different parts of the world, however, show that bitter vetch might have well been a 'regular' element of the human diet, the toxicity diminished by soaking in water prior to cooking and mixing with, for example, wheat (e.g. Dönmez 2005; Valamoti *et al*. 2010).

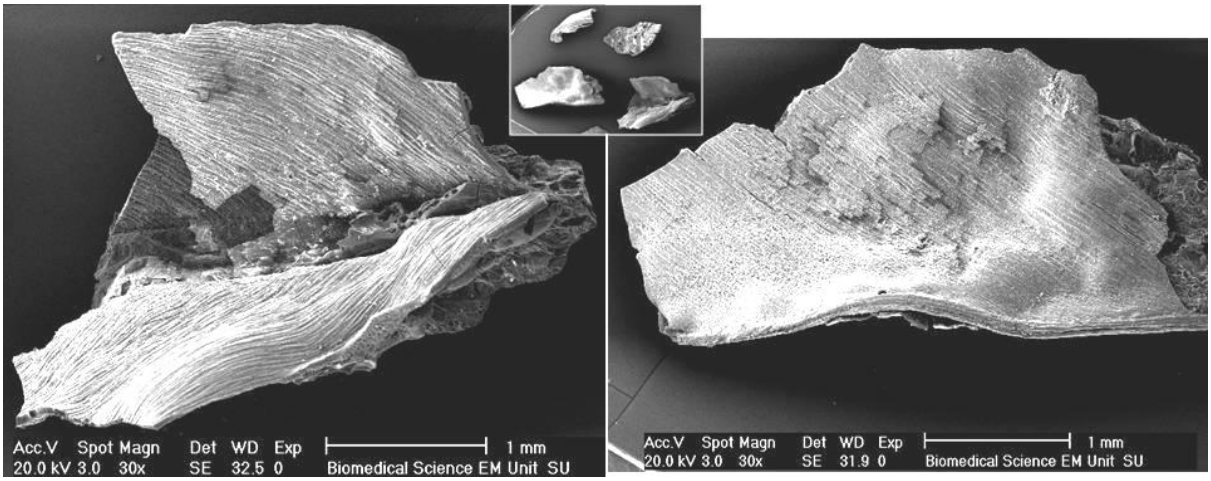


Figure 4.5 Fragments of the pea pod

Occasional/rare finds of chickpea and grass pea (the latter found in only one sample) may suggest that, even if of domesticated type, they might have grown as arable weeds similar to wild legumes. However, they were relatively abundant in the previously analysed samples from Pre-Level XII/South G phase (Fairbairn *et al*. 2005a), their number decreasing in later levels. They could have been consumed alongside 'staple' species (e.g. Peña-Chocarro and Zapata Peña 1999; Valamoti *et al*. 2010), and/or in combination with cereals, enriching the protein level of the diet (Butler *et al*. 1999) and are, therefore, included with the legume crops. Overall, the abundance and frequency of pulse remains show a potentially significant

role of legumes in the human diet (as a good source of plant protein), while both products and by-products (pulse chaff) of legume production could have been a valued source of animal fodder (Palmer 1998a; Butler *et al*. 1999; Fairbairn *et al*. 2005a).

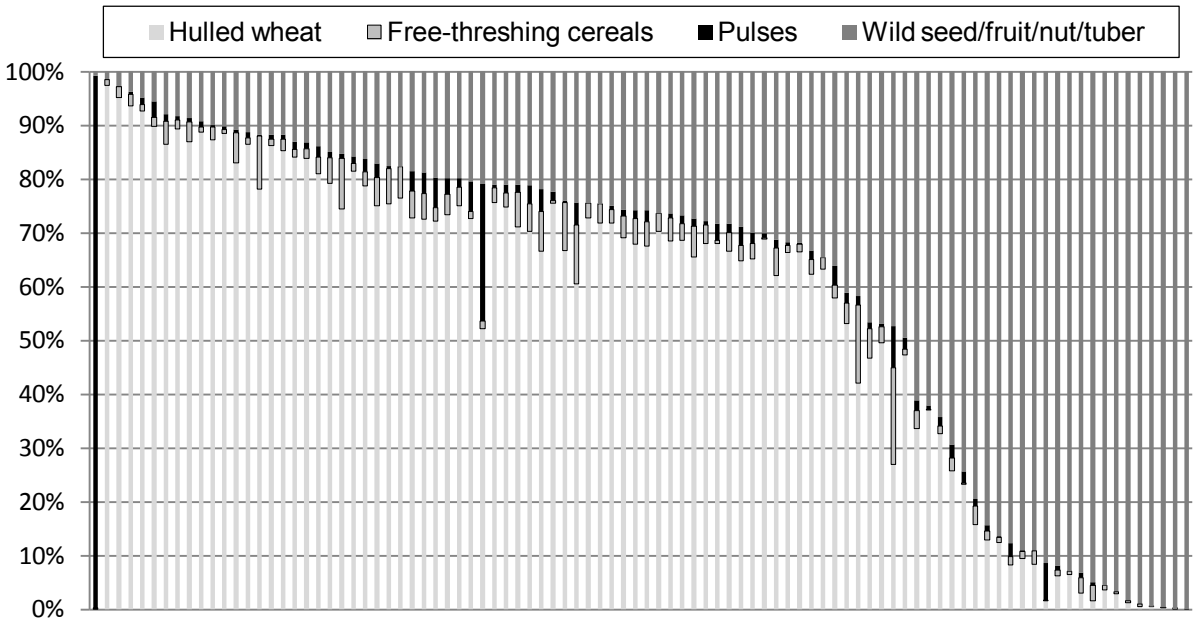


Figure 4.6a Relative proportions of the three crop groups and wild taxa across the samples

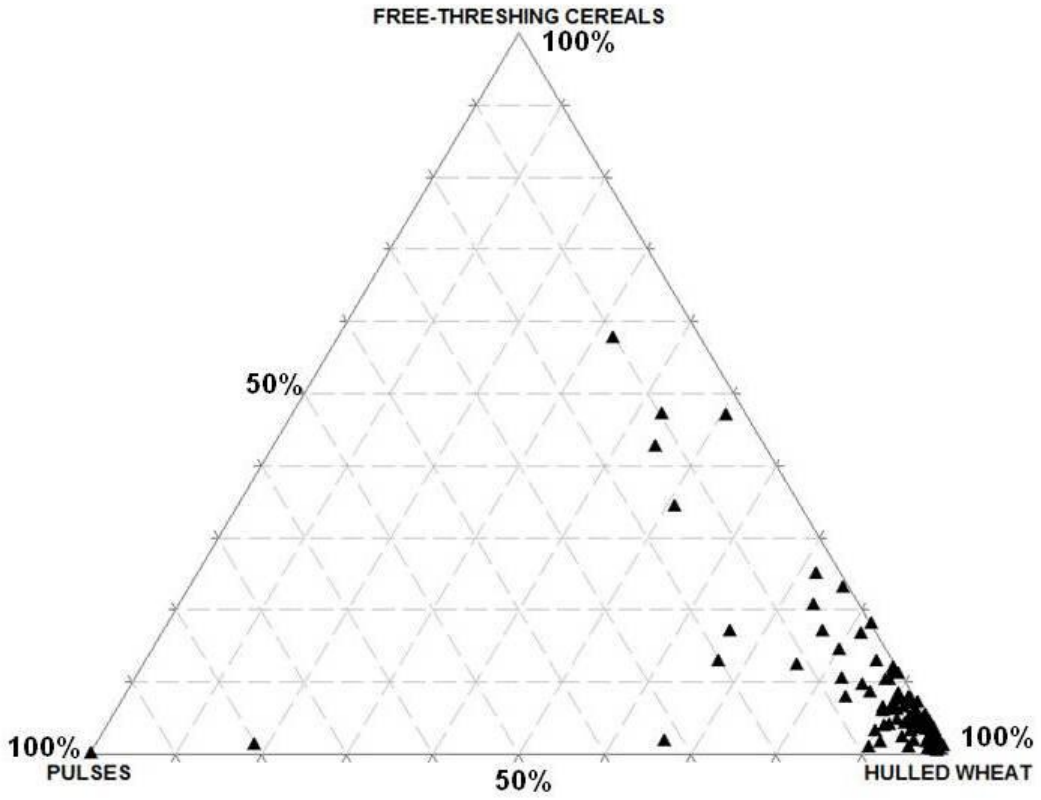


Figure 4.6b Relative proportions of the three crop groups (▲- samples)

The importance of hulled wheats, free-threshing cereals and legumes at Çatalhöyük may be tentatively assessed by comparing their relative quantities in the assemblage. Based on the proportions of crop types (Fig. 4.6a, b) and their plant parts (Fig. 4.7a, b), it could be concluded that hulled wheats were central to the crop production. Taking into account the

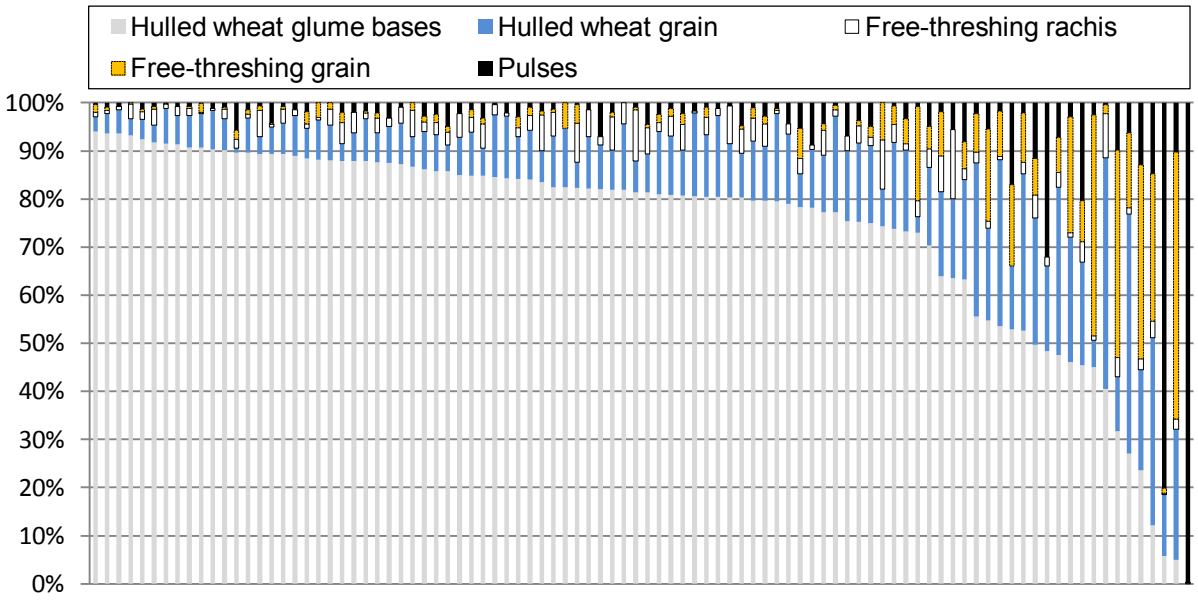


Figure 4.7a Relative proportions of crop plant parts across the samples

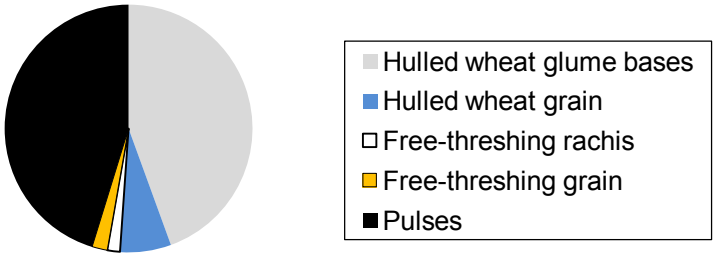


Figure 4.7b Relative proportions of crop plant parts in the assemblage

relatively high preservation potential of hulled wheat glume bases (Hillman 1981, 1984b) compared to unlikely survival of pulse 'chaff', and the charring bias affecting primarily chaff of free-threshing cereals (Boardman and Jones 1990), the importance of the three crop types was further explored based on the proportions of grain/seed across the individual samples, and the assemblage as a whole (Fig. 4.8a, b). Whereas hulled wheat grain outnumbers the two other grain/seed types in majority of the samples, it appears that the overall contribution of pulses to the whole crop assemblage exceeds that of cereal grains. This is, however, due to the high number of lentils derived from an *in situ* burnt store (the lentil-rich sample Fl. 144

from Building 1), while other crop types were recovered in smaller concentrations from a variety of contexts. When the lentil sample is excluded (Fig. 4.9a, b), the obvious predominance of hulled wheat grain in the assemblage supports the initial impression of the potentially greater importance of hulled wheat compared to two other crop types.

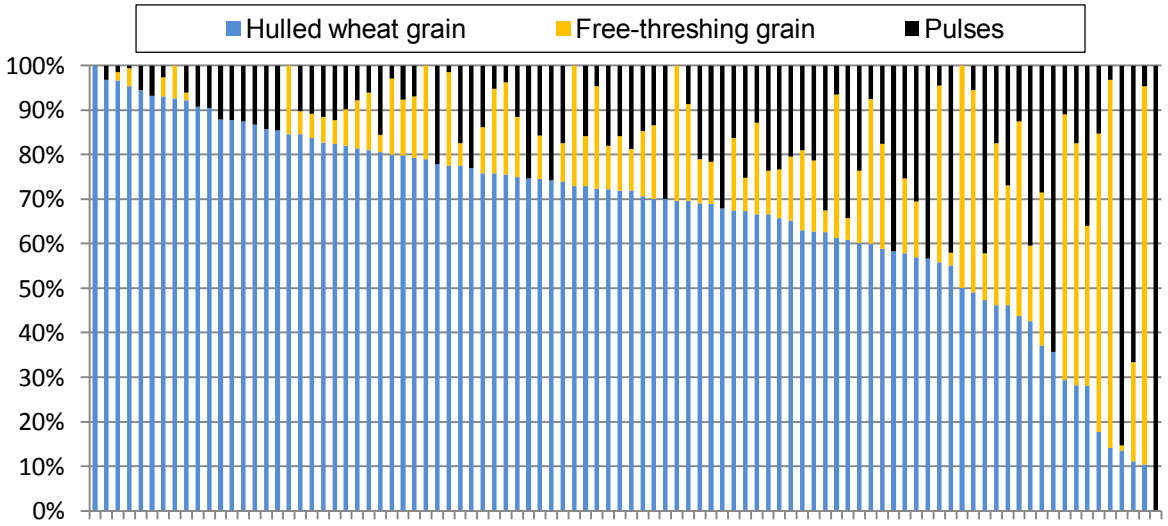


Figure 4.8a Relative proportions of grain/seed across the samples; the lentil sample included

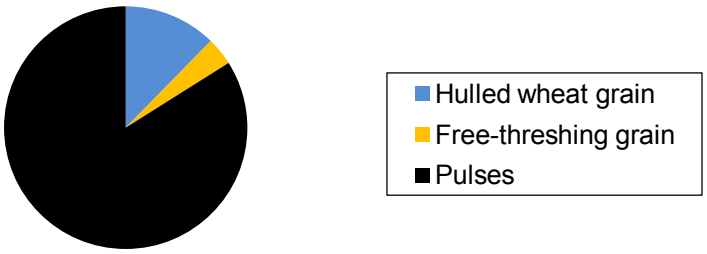


Figure 4.8b Relative proportions of grain/seed in the assemblage; the lentil sample included

4.3.3 **Classification of samples based on the crop content**

A simplified overview of the crop content in the assemblage was provided by amalgamating the main crop types into three groups, based on their 'behaviour' in post-harvest processing (Hillman 1981, 1984b) and the possibility that taxa from the same group could have been grown together (Jones and Halstead 1995). The key types are: hulled wheat (einkorn, emmer, 'new type' wheat), free-threshing cereals (free-threshing wheat and barley) and pulses (lentil, pea, bitter vetch, chickpea, grass pea). Some examples of cereals and pulses grown together were documented in the region of Asturias in Spain (peas and broad beans growing with

hulled wheats; A. Bogaard pers. comm.); they are, however, harvested and processed separately (Peña-Chocarro 1999).

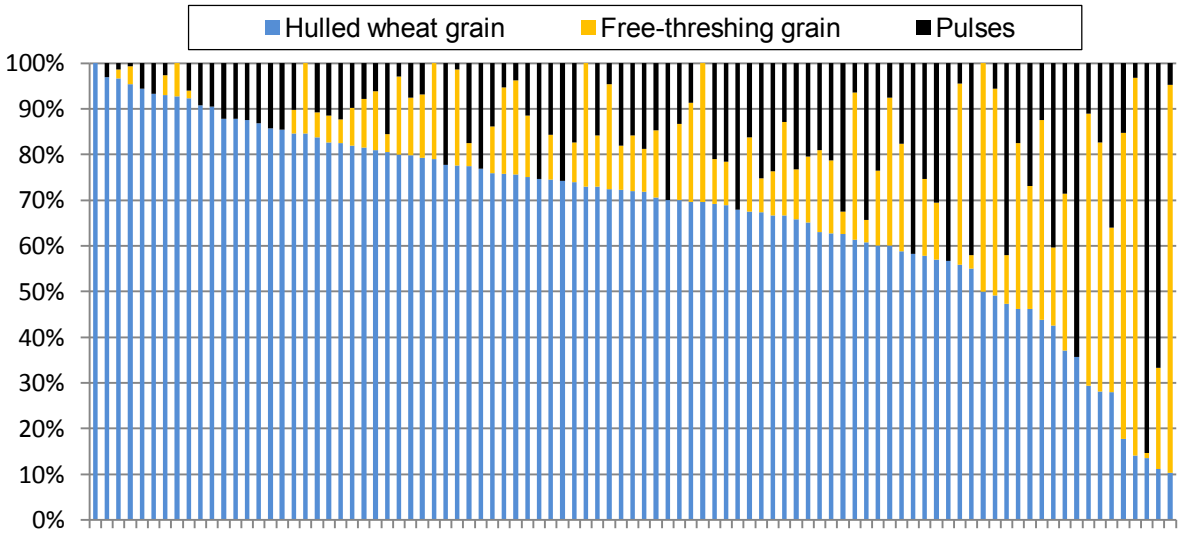


Figure 4.9a Relative proportions of grain/seed across the samples after the removal of the lentil sample

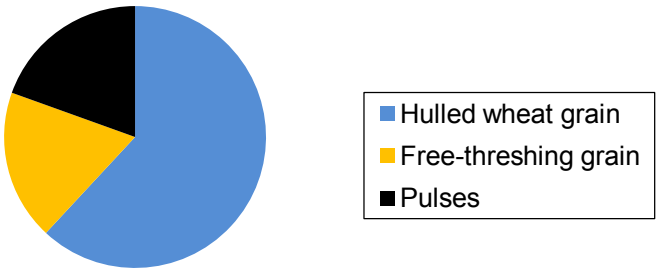


Figure 4.9b Relative proportions of grain/seed in the assemblage after the removal of the lentil sample

In order to establish the quantitative contribution of the crop groups to the assemblage, the total number of remains of each group, and their overall ubiquity (number of samples in which they occur) were examined (Table 4.3), and their proportions in the crop content of the samples compared (Fig. 4.10). In terms of the representation of different plant parts/elements of the three crop groups, the hulled wheat component was dominated by glume bases found in all samples analysed (hulled wheat glume bases made up 87% of the total hulled wheat component; Fig. 4.11a). The vast dominance of hulled wheat glume bases over hulled wheat grain stands in contrast to the somewhat greater abundance of free-threshing cereal grain in comparison to rachis segments (*c.* 55% of the free-threshing cereal component is composed of grain; Fig. 4.11b); on the other hand, rachis segments are more ubiquitous, occurring in 92 samples, while free-threshing grain is present in 72 samples.

Crop type	Abundance (number of items)	Ubiquity	
		count	%
HULLED WHEAT	**47403**	**94**	**100.00**
Hulled wheat grain	2388	93	98.94
Hulled wheat glume bases	45015	94	100.00
FREE-THRESHING CEREALS	**2754**	**94**	**100.00**
Free-threshing cereal grain	1076	72	76.60
Free-threshing cereal rachis	1678	92	97.87
PULSES	**45830**	**92**	**97.87**

Table 4.3 The abundance and ubiquity of the three crop groups

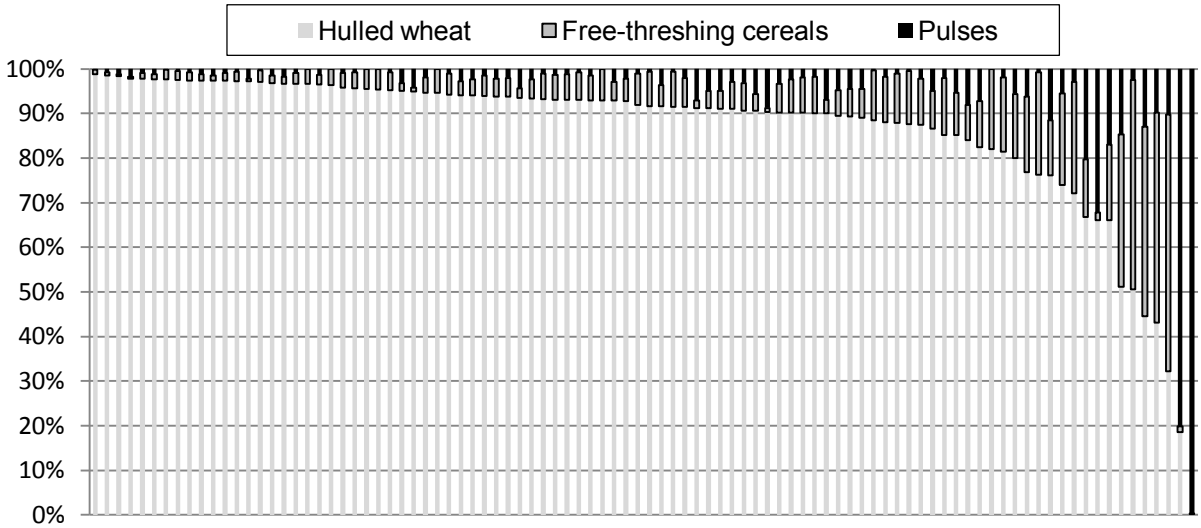


Figure 4.10 Relative proportions of the crop groups across the samples

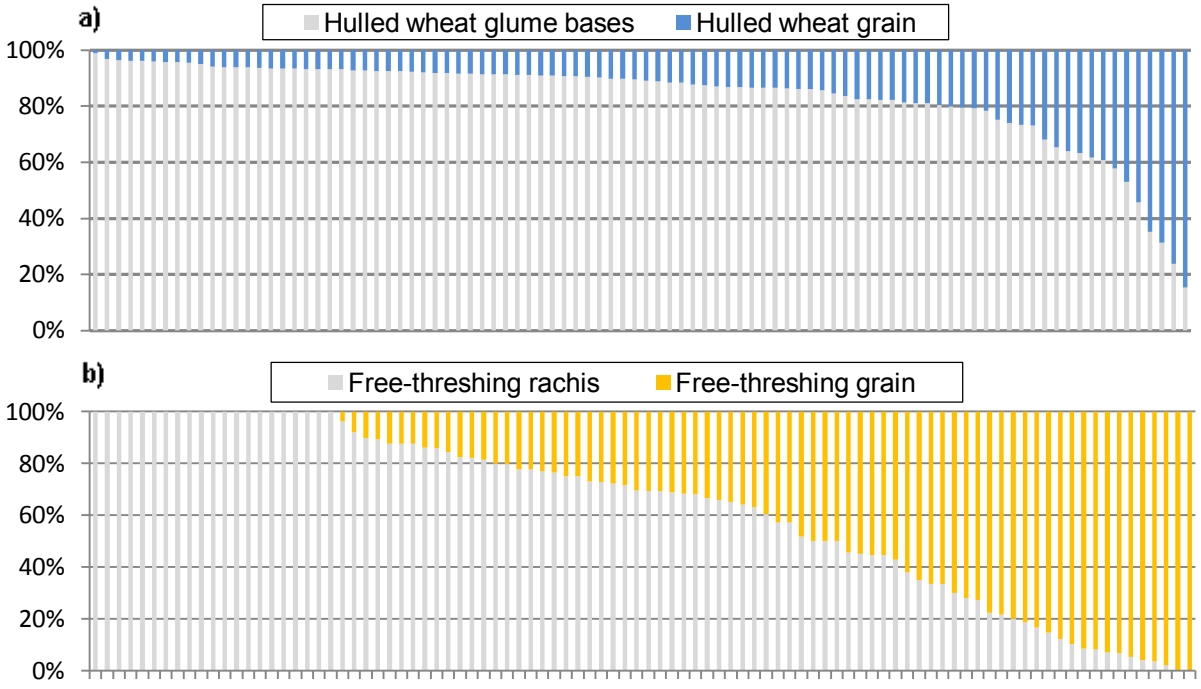


Figure 4.11a-b Representation of different plant parts within the two cereal groups

It was impossible to establish the relationship between pulse seed and 'chaff', since pulse chaff is much less likely to survive charring and, even if preserved it would have been underrepresented compared to pulse seeds (Jones 1984; Butler *et al*. 1999; Hald 2008). Fragments of pods and stalks discovered in some of the samples were not suitable for any meaningful calculation (i.e. in hulled wheats a glume base is countable and offers a basis for the estimate of number of spikelet forks, associated grains etc, as do rachis segments for free-threshing wheat; Section 3.6.1).

In order to clarify differences among the samples in terms of their crop composition, and to structure subsequent consideration of the ways in which plant remains entered the archaeobotanical record (Ch. 5), the samples were classified according to the predominant crop group they contain. Based on the proportions of the three defined crop groups (Fig. 4.10) an arbitrary threshold of 70% within the crop content of individual samples (excluding wild/weed taxa) was considered suitable for distinguishing between the samples. All crop remains (cereal grain and chaff, and pulse seeds) were included in the calculations. Acknowledging the tendency of hulled wheats to generate more chaff which is likely to become charred and preserved as opposed to chaff of free-threshing cereals and pulses (Hillman 1981; Jones 1984), and the greater potential of glume basis to survive charring compared to e.g. barley rachis (Boardman and Jones 1990), it is conceived that, the use of counts/percentages of grains only would not provide a *real* indication of the abundance and ubiquity of hulled wheat. On the other hand, amalgamating elements derived from different crop processing stages – e.g. hulled wheat chaff and free-threshing grain – would render the sample groups unsuitable for further comparison and considerations in terms of crop-processing (Jones 1990). A detailed examination of presence and proportions of plant parts of different crops in the samples is carried out within the crop processing analysis (Section 5.3.1).

Hulled wheat samples

The crop content of 84 samples consists predominantly (70% or more) of hulled wheat grain and/or glume bases. Of these, 63 contain at least 90% hulled wheat material, while crop content of four samples consists exclusively of hulled wheat grain and chaff. Within the remaining 30% or less of other crop material in this group of samples, free-threshing cereals are generally present in higher proportions than pulses (Fig. 4.12).

Pulse samples

The crop content of two samples consists predominantly (over 70%) of legume seeds; as noted above, one of them (Sample 144) contains solely lentils (99.87%).

'Mixed-crop' samples

In eight samples all three crop groups are represented, but none of them constitutes 70% or more of crop content. In four of these, percentages of hulled wheat (of around 50%) are still remarkably higher than those of free-threshing cereals and/or pulses. The remaining four mixed samples contain similar proportions of hulled wheat and free-threshing cereal (between 60% and 40% of each group). In sum, all 'mixed-crop' samples contain a fairly even mixture of all three crop groups.

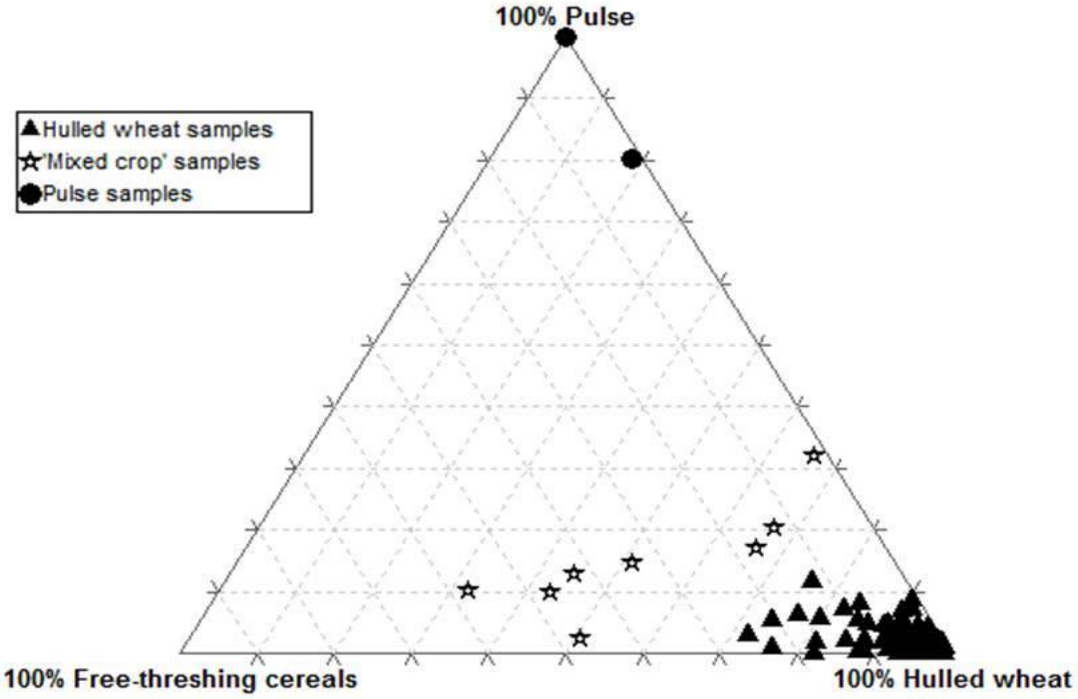


Figure 4.12 Classification of samples based on the crop content

4.3.4 **Summary**

This preliminary classification of the samples outlines to some extent the sorts of activities/processes that resulted in differential archaeobotanical composition of the samples; relevant processes and their effects are discussed in Ch. 5. For now it can be noted that the relatively homogeneous crop material in the hulled wheat and pulse samples are potentially assignable to unmixed crop processing stage(s) and hence will form the primary basis for

inferences regarding crop husbandry practices (Jones 1981, 1992; Bogaard *et al*. 2005b). Mixed-crop samples presumably contain remains from a number of activities deposited together and/or mixed after initial deposition (e.g. crop processing residues dumped into domestic fires, mixed with contents of dung used as fuel; disturbance of deposits characteristic for middens and trampled areas etc).

4.4 Wild taxa

In the selected samples, 104 wild plant types were recognised, including 'cf.', genus-, family- and type-level, and excluding indeterminate identifications (Table 4.4). A large number of them are attested by the presence of charred remains: seeds and seed endosperms (the majority of taxa), complete or fragmented fruit stones (*Prunus spinosa* L. type) and nut shells (*Amygdalus orientalis* L. type - almond, *Pistacia terebinthus* L. - pistachio and *Quercus* L. - acorn nutshell, cupula and nut kernels), complete or fragmented seed pods/capsules (mainly *Crucifereae*), rachis segments of medusa grass (*Taeniatherum caput-medusae* L.*)*, reed culm nodes (*Phragmites australis* (Cav.) Trin.) etc. As noted above, mineralised remains were also encountered - e.g. highly ubiquitous and abundant calcareous hackberry fruit stones (*Celtis* L.), seeds of gromwell and stoneseed (*Buglossoides arvensis* L. and *Lithospermum officinale* L. types), spikerush (*Eleocharis* R. Br.) and duckweed (*Lemna* L.). A small number of mineralised club-rush (*Bolboschoenus glaucus* (Lam.) S.G. Smith) seeds were discovered in the samples from stabling contexts (Space 199).

In this preliminary account, remains of wild taxa are discussed within three broad categories: a) collected taxa - fruits, nuts and tubers, b) reed, and c) wild/weed taxa, whereas some identifications are excluded from further consideration. Table 4.5 provides a taxonomic list for the groups and shows total numbers of remains and ubiquities (for each taxon and a whole group); Figure 4.13 illustrates proportions of the general groups of wild taxa across the samples.

4.4.1 Fruits, nuts and tubers

Charred remains of gathered fruits and nuts were commonly found in the samples (in 81 out of 94), sometimes in significant concentrations (e.g. fragmented nut shell from *c*. 45 almonds

in a sample from Space 181), and they likely represent residue from cleaning/consumption. All of the recorded species were also noted in previous analysis (Fairbairn *et al*. 2005a). Ethnographic research shows that wild fruits and nuts have often been used as human food in the region (Ertuğ-Yaraş 1997; Ertuğ 2000; Mason and Nesbitt 2009), while acorns have also been a fodder source (Palmer 1998a; Ertuğ 2000). Charcoal analysis has revealed that wood remains of the fruit/nut taxa, especially oak, were present throughout the site's lower Neolithic sequence (Asouti and Hather 2001; Asouti 2005b); hence some of the remains may have entered the record attached to branches, twigs etc used as fuel and fodder. Hackberries are the most abundant and most ubiquitous among fruit/nut remains; they are still collected and consumed in Anatolia (Ertuğ-Yaraş 1997). Hackberry nutlets can survive in archaeological deposits without being charred (Shillito *et al*. 2008; Shillito and Almond 2010), and they are likely overrepresented in the assemblage compared to the charred fruit/nut remains (Fairbairn *et al*. 2005a).

The recorded fruit- and nut-bearing species are dryland woody perennial taxa (trees or shrubs) nowadays occupying open (park) woodland at the foot of the mountains surrounding the Konya plain, and the forests in the uplands (see Section 2.3.1.3). In the past they could have also grown on the plain, closer to Çatalhöyük, provided there were areas with a low water table nearby (Asouti 2005b). They can invade cultivated fields but are unable to set seed under disturbed conditions, characteristic of arable and ruderal areas, and are therefore excluded as potential weeds in crop husbandry considerations (Bogaard *et al*. 2005b).

Complete charred tubers, tuber stems and parenchyma fragments probably deriving from club-rush (*Bolboschoenus* sp.) were recovered from 36 samples. The potential economic use of the plant has been documented ethnographically and explored experimentally; it ranges from a possible food resource (starch-rich club-rush tubers and nutlets) to stabilizing material for mudbrick (tubers and stems), to weaving material for floor and wall coverings/mats (Erkal 1999; Wollstonecroft and Erkal 1999; Wollstonecroft *et al*. 2008). For instance, Erkal (1999) observed club-rush tubers within mudbrick house walls in the village of Küçükköy near Çatalhöyük. Here roots and tubers of club-rush are often intentionally dug up with the mud and used to add strength to the structure of the mudbrick; when the walls begin to decay and tubers fall out, the villagers throw them into fire. The evidence from some late Epipalaeolithic and early farming sites in the Near East has been interpreted to suggest a food role for club-rush seeds and tubers (e.g. Hillman *et al*. 1989a, b; Hillman 2000b; Savard *et al*.

2006; Wollstonecroft *et al.* 2011). At Çatalhöyük club-rush remains were relatively common in the previously analysed samples, but no pure concentrations (e.g. cashes, stores) of seeds or tubers have been discovered, and the remains were not interpreted as a foodstuff (Fairbairn *et al*. 2005a), though the role of tubers as a food source has been suggested based on their apparent association with grinding slabs in several archaeological contexts (Atalay and Hastorf 2005). Micromorphological analysis of aggregates of large coarse animal dung (from Space 181) - probably cattle or equid - have detected tubers/parenchyma fragments in these remains, pointing to the possible role of tubers as fodder (Matthews 2005a).

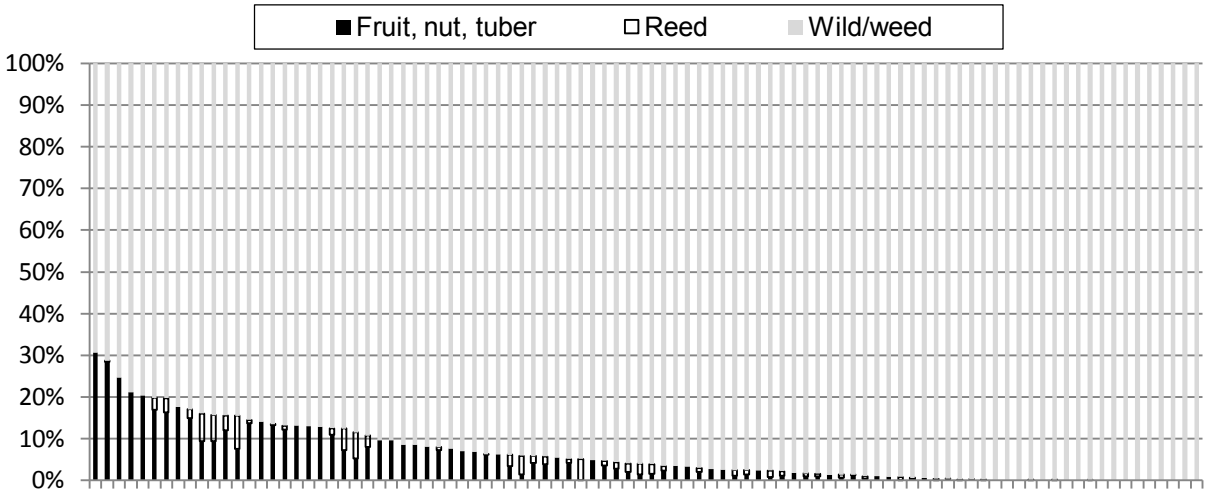


Figure 4.13 Proportions of the general groups of wild taxa across the samples

4.4.2 **Reed**

Reed (*Phragmites australis* (Cav.) Trin.) is a long-lived wetland grass with bamboo-like protein-rich stems widely used as fodder, fuel, fertiliser, and thatching material (Grime *et al*. 1988). Culm nodes of reeds were recorded in 49 samples; no definite reed seeds have been encountered and this may be due to the fact that reed rarely sets seed, and reproduces via vegetative organs (rhizomes; Davis *et al*. 1965), which enables it to recover from grazing, cutting, trampling (Grime *et al*. 1988).

Unlike fruits and nuts (and tubers) that were most probably gathered for food (and perhaps fodder; Fairbairn *et al*. 2005a; Matthews 2005a), reed was most likely used as fuel, fodder and building/craft material (Matthews 2005a, 2010, in press/2013; Rosen 2005; Ryan 2011). Micromorphological and phytolith analyses documented presence of reed stem in various

deposits across the site, for instance in fire installations, pointing to its use as fuel (e.g. tinder), and in remains of cattle and other herbivore dung, suggesting reed as an additional part of animal diet - an observation also supported by sheep dental microwear evidence (Henton 2010, in press/2013). Phytoliths of reed leaves and stems were also present in a range of other contexts, possibly resulting from the use of reed as craft (basketry, matting) and construction (e.g. roofing) material (Fairbairn *et al*. 2005a, Matthews 2005a, 2010, 2012; Rosen 2005; Ryan 2011).

Reed exploits moist to waterlogged habitats, but also survives well in disturbed and fertile conditions (Grime *et al*. 1988) and commonly occurs in arable fields around Çatalhöyük today (pers. observation). It is considered an invasive plant and, while its relative abundance in the archaeological deposits could reflect extensive areas of wetland and marshes on the alluvial plain near the site, it could equally point to the (significant) presence of anthropogenically disturbed (e.g. cultivated) conditions near the settlement, adjacent to wetland or in formerly wetland areas.

4.4.3 **Wild and/or weed taxa**

Ninety-two identification categories were included in this group and of these, 23 were considered too general/indeterminate for classification and hence are not discussed in the present account (e.g. family-level identifications); they are included only in the initial calculations (Table 4.4). Absolute counts of rachis and seed of *Taeniatherum caput-medusae*, shown separately in Table 4.4, are from here onwards combined. The remaining 69 identifications comprise a wide range of species, of which many, according to the published habitat information, are potential arable weeds while they could have at the same time been a grazing/fodder source (Davis *et al*. 1965-1988; van Soest 1987; Grime *et al*. 1988; Fairbairn *et al*. 2005a). Many of them have ethnographically documented uses as food or aromatic and medicinal plants (Lyle-Kalças 1992; Ertuğ-Yaraş 1997; Ertuğ 2000, 2004b; Kültür 2008). For example, some species that grow in arable/ruderal habitats, such as fat hen (*Chenopodium album* L.), black bindweed (*Polygonum convolvulus* L.) and some docks and sorrel species (*Rumex* L.) are all potentially edible, especially their leaves which have been used as wild 'greens' (Ertuğ 2000). They were all recorded in the Çatalhöyük *seed* assemblage (Fairbairn *et al*. 2002, 2005a; the present study), which could, in fact, argue against the use of leaves, since plants decline in nutritive value as they age and tend to become unpalatable once the

seed has formed (van Soest 1987: 20). Seeds of herbaceous wetland/marsh taxa including several sedge species (*Cyperaceae*), rushes (*Juncus* L.) and small-seeded grasses (*Gramineae*) were quite common, whilst specifically aquatic species (characteristic of stagnant water), such as duckweed (*Lemna* L.), pondweed (*Potamogeton* L.) and water-plantains (*Alisma* L.) were rarely encountered. Another set of species includes taxa potentially growing in a number of different vegetation formations characteristic of the landscape around Çatalhöyük (steppe zone, park woodland, sand ridges and disturbed habitats - Asouti and Hather 2001; Fairbairn *et al*. 2005a; Fairbairn 2005); these include *Artemisia* types, small-seeded wild legumes, *Boraginaceae* and *Labiateae* species, grasses (*Eremopyrum* (Ledeb.) Jaub. & Spach, *Taeniatherum caput-medusae* (L.) Nevski, *Stipa* L.) and so on.

An *a priori* distinction between 'natural' and arable/ruderal flora based on species' ecological preferences/tolerances is not feasible due to the wide range of growing conditions in which majority of the identified wild taxa occur (cf. Davis *et al*. 1965-1988; Grime *et al*. 1988). Multivariate statistical analysis shed further light on associations between species and hence their potential habitat of origin (Ch. 5-6). Here, various classifications and combinations of the selected 69 wild/weed identifications were carried out in order to achieve a relatively comprehensive preliminary picture of the diverse Çatalhöyük wild flora and to lay a foundation for further analysis. The most useful criteria for broad categorisation of taxa in the initial overview of the 'wild' component of the assemblage were the ubiquity of different species/types and their abundance.

The overall ubiquity of the wild/weed taxa is shown in Table 4.5; in order to make an initial distinction between 'frequent' and 'rare' species, an arbitrary minimum of *c*. 5% (=5 samples) of the samples in which any of the 69 taxa occurred was used. In this way, 45 taxa were considered reasonably common, while the remaining 24 were present in fewer than 5 samples and are regarded as rare (Table 4.6a, b). A single taxon was encountered in all but one analysed sample (*Bolboschoenus glaucus*). On the assumption that the wild/weed component of the crop-rich samples is directly associated with crops, this may indicate a remarkably rich and diversified weed flora. The taxa considered common based on the 5% sample-occurrence criterion are at the same time, with few exceptions, the most abundant (Table 4.7). For example, 14 'frequent' taxa are represented in the assemblage by around 400 items each. In contrast, 20 out of 24 'rare' species contributed less than 10 items each.

WILD/WEED TAXA	Number	Ubiquity	
FREQUENT	**of items**	count	%
Bolboschoenus glaucus (Lam.) S.G. Smith	10779	93	98.94
Leguminosae, small wild	6346	81	86.17
Polygonum aviculare aggregate	1060	76	80.85
Taeniatherum caput-medusae L.	617	68	72.34
Sporobolus R. Br.	5151	62	65.96
Carex L.	463	54	57.45
Descurainia sophia (L.) Webb	2782177	43	45.74
Aeluropus Trin.	11619	39	41.49
Convolvulus arvensis L. type	194	39	41.49
Bromus danthoniae Trin. type	80	34	36.17
Galium aparine L. type	92	32	34.04
Vaccaria pyramidata Medik.	89	29	30.85
Juncus L.	3909	27	28.72
Buglossoides arvensis L. type	102	27	28.72
Sideritis L. type	291	26	27.66
Eremopyrum (Ledeb.) Jaub. & Spach	43	23	24.47
Helianthemum Adans.	642	23	24.47
Rumex L.	559	23	24.47
Cornucopiae cucullatum L. type	85	21	22.34
Atriplex L.	168	20	21.28
Silene sp.	214	20	21.28
Vicia L./*Lathyrus* L.	31	18	19.15
Chenopodium L.	164	17	18.09
Salsola L.	45	17	18.09
Artemisia annua L. type	1724	14	14.89
Adonis annua/aestivalis L.	32	13	13.83
Centaurea sp.	31	12	12.77
Lavatera L. type	14	12	12.77
Crypsis aculeata (L.) Aiton type	380	11	11.70
Hordeum murinum L. type	13	11	11.70
Conringia orientalis L.	34	10	10.64
Thymelea passerina (L.) Cosson & Germ. type	27	9	9.57
Boreava orientalis Jaub. & Spach	20	8	8.51
Chenopodium album L. type	69	8	8.51
Eragrostis N.M. Wolf	653	8	8.51
Heliotropium L.	51	8	8.51
Malva L.	12	8	8.51
Campanula L.	7	7	7.45
Alisma L.	17	6	6.38
Beta L.	10	6	6.38
Eleocharis R. Br.	53	6	6.38
Androsace L.	39	5	5.32
Fumaria L.	10	5	5.32
Ziziphora capitata L./*persica* Bunge	50	5	5.32
Lemna L.	112	5	5.32

Table 4.6a Frequent wild/weed taxa (indeterminate wild/weed excluded)

The wild/weed component of the majority of samples is dominated by the 14 most frequent *and* most abundant wild/weed taxa suggesting a relatively uniform composition resulting from their similar origin. The majority of wild/weed species/types were also common in the previously analysed datasets (Helbaek 1964; Fairbairn *et al*. 2002, 2005a) and are briefly discussed below in terms of their potential roles; the sources and status of the wild/weed flora in the samples is assessed in more detail through taphonomic (Ch. 5) and multivariate/exploratory analysis (Ch. 6). Notably, *Descurainia sophia* (L.) Webb is at the top of the 'frequent and abundant' list; the proportions of *Descurainia* in relation to other wild taxa and the crop content of the samples are illustrated in Figures 4.14a-b. The fifteen samples where *Descurainia* seeds represent 70% or more of the total (crop and wild) remains are referred to as *Descurainia* samples (see below).

WILD/WEED TAXA RARE	Number of items	Ubiquity	
		count	%
Hordeum spontaneum C. Koch type	7	4	4.26
Polygonum convolvulus L.	4	4	4.26
Teucrium L.	21	4	4.26
Chenopodium chenopodioides L. type	4499	3	3.19
Galium verum L. type	43	3	3.19
cf. *Lallemantia peltata* L.	5	3	3.19
Anagallis L.	7	2	2.13
Erodium L'Hérit.	2	2	2.13
cf. *Potentilla* L. type	3	2	2.13
Ranunculus L.	2	2	2.13
Valerianella Miller	3	2	2.13
Verbena officinalis L.	8	2	2.13
Capsella Medik.	1	1	1.06
Euphorbia L.	2	1	1.06
Geranium L., small type	1	1	1.06
Linum L.	13	1	1.06
Papaver L.	2	1	1.06
Polygonatum Miller	9	1	1.06
Potamogeton L.	1	1	1.06
cf. *Secale* sp.	1	1	1.06
Stipa L.	20	1	1.06
Suaeda L.	8	1	1.06
Viola L.	1	1	1.06
Lithospermum officinale L.	1	1	1.06

Table 4.6b Rare wild/weed taxa (indeterminate wild/weed excluded)

Artemisia

This is a characteristic taxon of the treeless steppe vegetation of Central Anatolia (Davis *et al*. 1965: 22); several species of this genus were once dominant in this region but are reduced by

over-grazing. The minute-size seeds discovered in the selected samples most closely resemble *Artemisia annua* L.; previous analysis also recorded presence of *A. vulgaris* L.-type seeds (Fairbairn *et al*. 2005a). The bulk of *Artemisia* seeds were encountered in the wild-rich samples and they were particularly abundant in the sample from *in situ* burnt deposit in external space - a fire spot (Sample 3742 in Space 181) which contained *c*. 85% of the total number of *Artemisia* seeds in the assemblage; this sample also contained high numbers of bitter vetch seeds (and was therefore classified as pulse-rich, Section 4.3.3).

WILD/WEED TAXA	Number of items	Ubiquity	
FREQUENT and ABUNDANT		count	%
Descurainia sophia (L.) Webb	2782177	43	45.74
Aeluropus Trin.	11619	39	41.49
Bolboschoenus glaucus (Lam.) S.G. Smith	10779	93	98.94
Leguminosae, small wild	6346	81	86.17
Sporobolus R. Br.	5151	62	65.96
Juncus L.	3909	27	28.72
Artemisia annua L. type	1724	14	14.89
Polygonum aviculare aggregate	1060	76	80.85
Eragrostis N.M. Wolf	653	8	8.51
Helianthemum Adans.	642	23	24.47
Taeniatherum caput-medusae L.	617	68	72.34
Rumex L.	559	23	24.47
Carex L.	463	54	57.45
Crypsis aculeata (L.) Aiton type	380	11	11.70

Table 4.7 Frequent and abundant wild/weed taxa

Taeniatherum caput-medusae

Based on archaeological finds of concentrations of seeds and spikelets of two grasses, medusa grass (*T. caput-medusae*) and false wheatgrass (*Eremopyrum* sp.), Helbaek (1964) suggested the use of these wild plants as adornment; the concentrations could, however, represent residue from crop processing (hand-cleaning of grain), since the grass-dominated samples recovered in Mellaart's excavations were contaminated with remains of other taxa and their archaeological context does not seem to support the suggested use (Fairbairn *et al*. 2007). Both species are of steppe origin (Zohary 1973), while *Taeniatherum* also occurs in fallow fields and on waste ground. They were relatively frequent in the samples selected for this study - *Eremopyrum* seeds were found in 23 samples, *T. caput-medusae* grain in 60 samples, chaff in 32; the remains of medusa grass were also more abundant than seeds of false wheatgrass. Neither of the two grasses dominated wild content of any of the analysed samples.

Phytolith analysis of basket remains at Çatalhöyük revealed that *Eremopyrum* (syn. *Agropyron*) phytoliths were exclusively found in remains of neonatal burial baskets (Rosen 2005); not all infant burial baskets were made of this particular grass, but the respective phytoliths are found only in these particular contexts. Moreover, unlike other basketry materials (stems and leaves of grasses and sedges), in the case of *Eremopyrum* phytoliths from floral segments were often present in the neonate burials, perhaps showing intentional placement of inflorescence related to infant burial ideology (Rosen 2005). This may represent a source of *Eremopyrum* seeds in the assemblage additional to the possible weed origin.

Helianthemum

A sample from Mellaart's archive contained a large number of rockrose (*Helianthemum* Mill.) seeds, possibly intended for human consumption, though no ethnographic parallels for the use of *Helianthemum* seeds are known (Fairbairn *et al*. 2007). The species within the genus occupy dry calcareous places in scrub and steppe (Davis *et al*. 1965). In the present analysis, seeds of rockrose were found in 23 out of 94 selected samples. The majority of the remains derived from two contexts: *in situ* burnt deposit (fire spot) in external space (Space 181) with around 54% of the total *Helianthemum* seeds in the assemblage, and a fire installation/hearth in Building 1 (Sample 395) containing around 22% of the total *Helianthemum* seeds in the assemblage.

Small-seeded grasses

Several small-seeded grass types were recognised in the assemblage, but their number is not definite as the poor preservation and a high number of possible taxa (cf. Nesbitt 2006) limited the identification (Section 3.5). Their remains were most abundant in the wild-rich samples. Of the four frequent *and* abundant small-seeded grasses, three generally occupy wet places (e.g. *Aeluropus* Trin. grows at edge of *Phragmites* marsh and irrigation channels) and, more specifically, saline environments, for example saline flats and edge of salt marshes (*Sporobolus* R. Br.) and saline steppe and edge of saline lakes (*Crypsis* Aiton). *Eragrostis* N.M. Wolf grows in a variety of habitats (especially *E. minor* Host), and among them are wet places, lake shores, salt pans, but also edges of cultivated fields, ditches and roadsides; *Aeluropus* can also occur in abandoned cultivated fields (Davis *et al*. 1965-1988). Other salt-tolerant taxa in the assemblage include less common (and less abundant) *Chenopodiaceae* (*Suaeda* L., *Salsola* L., *Beta* L. and some *Atriplex* and *Chenopodium* species, e.g. *A. tatarica* L. and *C. chenopodioides* L.).

Juncus

Seeds and seed capsules of this wet-loving taxon were found, which are commonly dispersed by animal ingestion (Grime *et al*. 1990). Most rushes (*Juncus* L.) prefer salt-marsh environments but can also grow in (poorly drained) woodlands and meadows. Reed-like stems of rushes may have been used as basketry material, or for matting, bedding and thatching (e.g. Fahmy *et al*. 2008) and could have represented a grazing source (Popay and Field 1996).

Cyperaceae

The herbaceous riparian flora is further represented by three sedges (*Cyperaceae*); a large number of charred seeds of two of them - *Bolboschoenus glaucus* and *Carex* L. - were found, while silicified *Eleocharis* seeds occurred in low numbers in only a few samples (Table 4.6a); a small number of mineralised *B. glaucus* seeds were encountered in a sample from penning deposits in Space 199. In the analysed samples *B. glaucus* had a maximum ubiquity (99% - 93 out of 94 samples) and extremely high abundance; a similar situation was noted in previous work where association of this plant with animal feeding was suggested (Fairbairn *et al*. 2005a). Other uses may also be considered (see below).

B. glaucus seeds/nutlets were previously identified as *Scirpus/Bolboschoenus maritimus* (L.) Palla. (Helbaek 1964; Fairbairn *et al*. 2005a); however, recent investigation into morphology and anatomy of modern *Bolboschoenus* species in Europe (Hroudová *et al*. 2007) and south-west Asia (Wollstonecroft *et al*. 2011) revealed that, in addition to the widespread *B. maritimus*, *B. glaucus* (formerly known from European flora) also grows in Turkey (but is not recorded in *Flora of Turkey*); subsequent examination of archaeological specimens from sites in Syria (Tell Aswad and Tell Abu Hureyra) and Turkey (Hallan Çemi, Demirköy and Çatalhöyük) showed that they all belong to *B. glaucus* (Wollstonecroft *et al*. 2011). The main implication for the current study is different ecology of the two species: *B. maritimus* is a halophyte, but also thrives under non-saline conditions; *B. glaucus* is exclusively a freshwater plant, usually growing along rivers and also in field depressions, shallow pools etc. (Hroudová *et al*. 2007).

Ethnographic research in the Konya plain has shown that club-rush stalks are still used as building material, for filling cushions, and for weaving mats which are placed between wool carpets and floors in houses, or put on ceilings (Erkal 1999). The plant itself grows in large

stands (usually alongside reeds) in shallow water bodies in the area and is easily accessible (Wollstonecroft and Erkal 1999). A potential food role of club-rush (*Scirpus/Bolboschoenus*) tubers (see above) extends to seeds as well, as both are rich in carbohydrates. Indeed, club-rush nutlets were detected in human coprolites at the Late Pleistocene hunter-gatherer site of Wadi Kubbaniya in northern Egypt (Hillman *et al*. 1989a), and they were also recovered in large numbers from transitional/early farming sites in south-west Asia including the Epipalaeolithic/Neolithic Hallan Çemi Tepesi and Çayönü in Anatolia, Abu Hureyra in Syria and several early sites in East Jordan and the Levantine corridor (Hillman *et al*. 1989b; Rosenberg 1994; van Zeist and de Roller 1995; Hillman 2000b; Colledge 2001; Wollstonecroft *et al*. 2011). Experimental harvesting and processing of the nutlets and tubers showed that they can be easily transformed into food (e.g. gruel and bread) and it is proposed that they would have been a good (and perhaps major plant) source of energy and nutrients for the Late Pleistocene and Early Holocene populations of the Near East (Wollstonecroft *et al*. 2008, 2011). In the previously analysed archaeobotanical assemblage from Çatalhöyük, club-rush nutlets were the most ubiquitous and one of the most abundant seed types, suggesting their common use (Fairbairn *et al*. 2005a). However, their consistent occurrence in dung-containing deposits (e.g. charred seeds in dung-burning layers in Pre-Level XII/South G phase, mineralised seeds in penning areas in Level XII/South H), along some other taxa of probable grazing/fodder origin (e.g. small-seeded legumes and grasses) based on the ethnographic information (provided by local shepherds) on the preferred grazed vegetation, strongly suggest animal diet as the most likely entry route for club-rush nutlets (Fairbairn *et al*. 2005a).

Small-seeded legumes

The second most common wild type in the samples (occurring in 81 out of 94 samples) were small-seeded wild legumes, which include multiple genera – *Medicago* L., *Astragalus* L. and *Trigonella* L. as the most probable sources of remains, based on the seed morphology; less likely but also possible are *Melilotus* Mill. and *Trifolium* L. The vast number of species in these genera growing in central Turkey (e.g. 380 *Astragalus* species - Davis *et al*. 1969) constrained the identification of the specimens beyond genus level. Fairbairn *et al*. (2005a: 170-171) suggest a grazing/fodder origin for the seeds based on their consistent presence in the samples containing actual dung remains - particularly within supposed lime-burning contexts in the earliest levels of the site (in Space 181), and as mineralised dung pellets from penning layers - and information gathered from residents of the villages near Çatalhöyük. In

addition to their potential role in animal diet, several other uses of the species within the these genera have been reported for Central Anatolia, e.g. food and kindling/fuel, while some are considered harmful to animals (Nesbitt 1995; Ertuğ-Yaraş 1997; Ertuğ 2000). In the present study, the majority of small-seeded wild legumes seeds also derived from deposits in the external space/midden Space 181 (*c*. 75% of the total number of the seeds).

Polygonaceae

Trigonous *Polygonum* seeds likely belong to the knotgrass aggregate group (*Polygonum aviculare* agg.), a complex of annual herbs including *P. aviculare* L., *P. arenastrum* Boreau and *P. mesembricum* Chrtek (Davis *et al*. 1967). *P. aviculare* is a widespread, persistent cosmopolitan weed occupying cultivated ground, roadsides, waste places and dry land in general, and is able to survive in a variety of disturbed conditions (Grime *et al*. 1988).

Another genus of *Polygonaceae* family - dock (*Rumex* L.) was commonly encountered in the samples and it grows in more or less same habitats as *P. aviculare* agg. (waste places, fields, roadsides; *R. crispus* L. also along river banks and marshes - Davis *et al*. 1967). The majority of *Rumex* seeds in the assemblage were discovered in a wild-rich sample (5019) derived from a fire installation in Building 3 (*c*. 82% of the total *Rumex* seeds); the sample also contained a high number of *Polygonaceae* seed endosperms most probably belonging to *Rumex* seeds, and only few remains of other taxa. The relatively 'pure' concentration of *Rumex* seeds maybe suggests deliberate collection. Ethnographic sources note the use of green parts ('greens') of some *Polygonum/Rumex* species for food and as medicine (Ertuğ-Yaraş 1997; Ertuğ 2000), while experiments at Abu Hureyra showed that knotgrass seeds can be roasted and ground into flour (Hillman 2000b). Based on this, finds of dock and knotgrass (and club-rush) seeds from several Late Epipalaeolithic/Early Neolithic sites in north Iraq and south-east Turkey have been interpreted as foodstuffs (Savard *et al*. 2006)

Both knotgrass and dock were identified in the previous work at Çatalhöyük (Fairbairn *et al*. 2005a). A very small number of seeds (a total of 4) of another taxon from the same family were discovered in few samples analysed within this study - *Polygonum* (syn. *Bylderdykia, Fallopia*) *convolvulus* L., a climbing arable weed occupying fields and scrub, and widespread in cereal crops (Davis *et al*. 1967; Grime *et al*. 1988).

Descurainia sophia

Oil-rich seeds of a small-seeded crucifer, wild mustard/flixweed (*Descurainia sophia* (L.) Webb.), were by far the most numerous in the assemblage (98% of the total wild content). In fact, a certain number of wild-rich samples were almost entirely composed of this taxon (Figure 4.14a, b). *Descurainia* plant forms dense stands in waste/ruderal areas and can also grow in arable fields (Davis *et al*. 1965). In this perspective, it could be considered an unwanted inclusion in the crop harvest and the seeds could represent discarded by-products of crop-processing; the presence of seeds in the samples from fire installations (oven and hearth in Building 1) could support this interpretation. However, a vast majority of the seeds were recovered from storage contexts (bins and a basin in Building 1) or were directly associated with them (see below). Moreover, from a crop processing point of view, the composition of samples dominated by *Descurainia* fits that expected for a fully processed stored seed: prevalence of a single seed type, with other components present in very small quantities (Hillman 1981, 1984a).

Previous analysis at Çatalhöyük recorded high concentrations of small-seeded *Crucifereae* (initially identified as *Sisymbrium* type) charred *in situ* in various contexts, particularly in Building 1 (Fairbairn *et al*. 2002, 2005a). This building had two major phases of occupation, separated by a series of burning events across the structure and demolition of some internal features (Cessford 2007b). In these burning 'episodes', large volumes of plant remains were preserved charred *in situ*; the destroyed parts of the building were filled up with rubble and

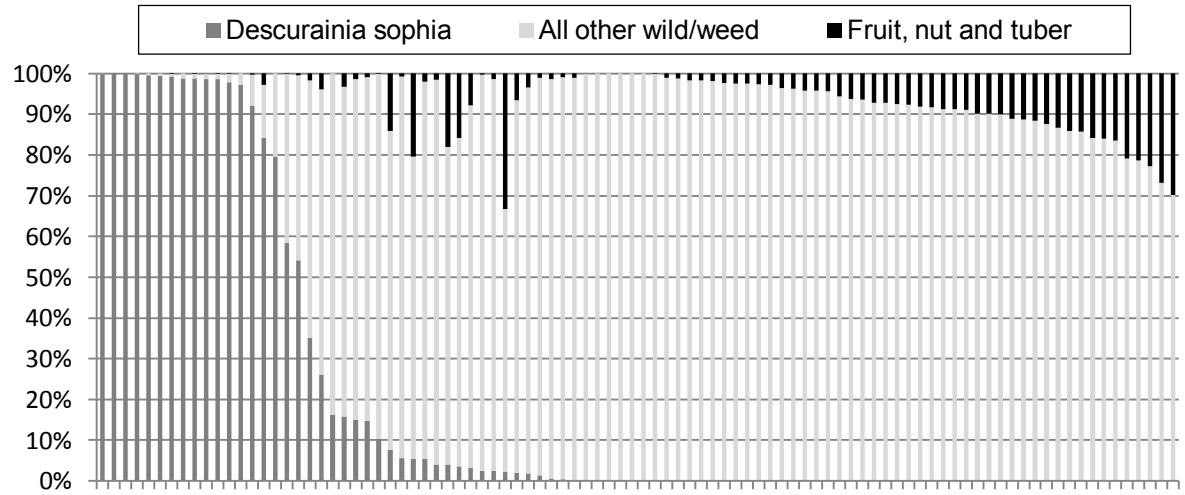


Figure 4.14a Relative proportions of *Descurainia sophia*, other wild/weed taxa (including indeterminate wild/weed) and the fruit, nut and tuber group

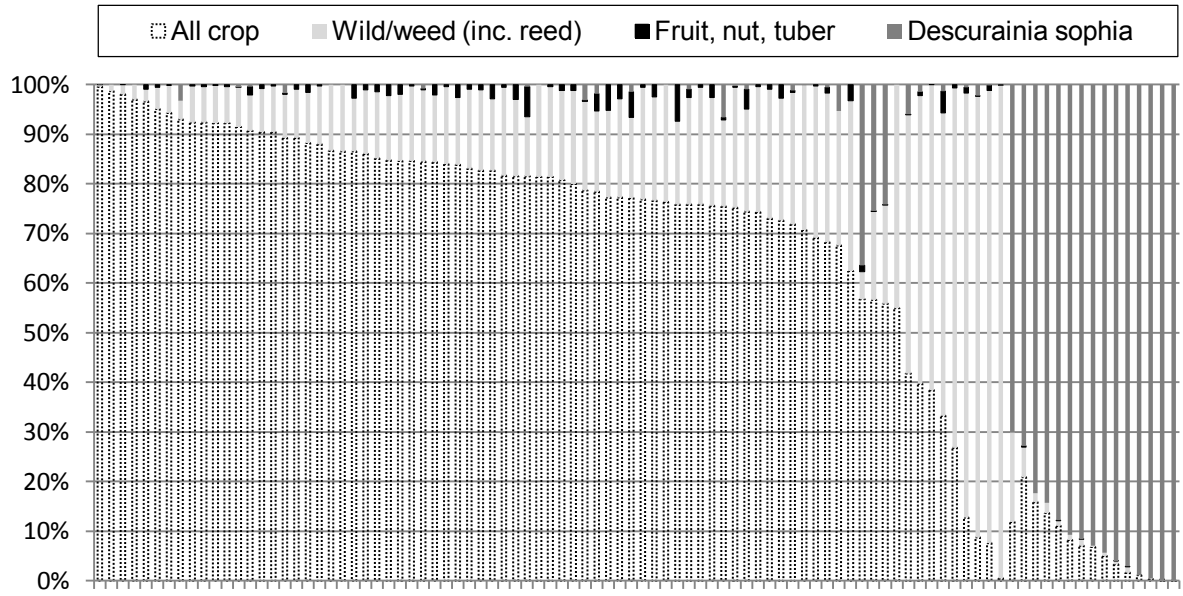


Figure 4.14b Relative proportions of *D. sophia*, wild/weed taxa (including reed and indeterminate wild/weed), fruit, nut and tuber group, and crop content

the post-burning occupation continued, including some modifications of the structure and creation of new features. In the deposits from the initial phase of the occupation, small crucifer seeds were discovered in association with a lentil bin, in a basin, and on floors in various parts of the building (Fairbairn *et al*. 2005a). Based on their presence all across the structure, it has been suggested that they, given their high oil content, may have been used to help (accelerate/control) the process of burning (Cessford 2007b: 460). However, as both previous and present analysis reveal, *in situ* burnt small crucifer seeds occurred in similar deposits (basin, floors, lentil bin) in later phase of the occupation as well, pointing towards their continuous presence/use throughout the life of the building.

Helbaek (1964) reported finds of small-seeded cruciferous plants (*Capsella bursa-pastoris* (L.) Medicus and *Erysimum sisymbrioides* C.A. Mey) in a grain bin and suggested they could have represented a source of oil. Detailed examination of the sample archive from Mellaart's excavations revealed more samples of almost pure *Capsella* and *Descuriania* seeds and offered further support for the proposed practice of collection, processing and storage of oil-rich crucifer seeds at Çatalhöyük (Fairbairn *et al*. 2007). Moreover, high volumes of *Descurainia* seeds burnt *in situ* have been recovered from storage bins in another burned building (Building 52) unearthed in recent excavations (Bogaard *et al*. 2005a). Whether it was growing as a weed in arable fields or as a ruderal plant, *Descurainia* (and possibly other wild crucifers) was most probably a targeted resource, used as oil, flavouring and so on,

similar to some other cruciferous taxa which are in use today or have been in the recent past (Ertuğ-Yaraş 1997; Zohary and Hopf 2000; Willcox 2002b).

4.5 Continuity in plant use over time

Based on the data from the selected assemblage, virtually no changes through time have been noted in the range of crop and fruit/nut/tuber types, and the major (i.e. frequent and abundant) wild/weed taxa. As shown in Table 4.8, the majority of crop types are found throughout the site's levels/phases. Sporadic finds of chickpea and grass pea may reflect their presence as contaminants of sown crops, though their noted abundance in the earliest occupation levels (Fairbairn *et al*. 2005a: Table 8.2) indicates that they may have (initially) been part of the rather diverse crop spectrum, but perhaps declined in importance through time. The appearance of taxa in the fruit, nut and tuber group is more or less consistent; the seeming absence of almond from Level XII/South H to Level VII/South M is a product of the inclusion of a number of almond-type nutshell fragments within the *Prunus/Amygdalus* type due to their bad preservation and thus imprecise identification. Moreover, Level VI.B/South N and North F phases are represented by a very small number of samples (i.e. fewer than 3) which may explain the absence of some relatively frequent taxa, such as the otherwise omni-present and highly visible hackberry (*Celtis*). The proposed decrease in the use of fruits and nuts towards the upper end of the analysed time sequence (Ağcabay *et al*. 2001) is not supported by the record now available. The previous impression may be due to differences in the sampled deposits, for example, if early occupation phases yielded (only) samples from external areas where (large-scale) processing of fruit/nut may have taken place (Fairbairn *et al*. 2005a: 190), as evidenced in the present study by the numerous almond shell fragments found in a single deposit in Space 181 (Section 4.4.1). The potentially unchanged role of fruits and nuts is supported by finds of clusters/caches of almond and acorn in later levels, i.e. in Level VI/South N-O (Helbaek 1964) and in Building 1 (Fairbairn *et al*. 2005a: 159), and the overall significant quantities of fruit and nut in Building 3 (Cane *et al*. 2012).

Similar to crops, most of the frequent and abundant wild taxa are found in all or the majority of the levels/phases, most notably *Bolboschoenus*, small-seeded legumes, *Polygonum*, *Aeluropus*, and *Taeniatherum*, followed by *Carex* and *Descurainia*. With the exception of the likely collected *Descurainia*, if some/all of these taxa are present as arable weeds, they may

imply similar crop growing conditions maintained over the long period of the site's early-mid Neolithic occupation. If they (also) represent an aspect of livestock diet, and derive from burning of dung of grazing animals, as has been suggested for some of the taxa (e.g. *Bolboschoenus,* small-seeded legumes, small-seeded grasses - Fairbairn *et al*. 2005a), then they could signify the constant use of dung as fuel, and perhaps the similarity in the choice/availability of animal feed throughout the period.

Hodder phase	South G	South H	South J	South K	South L	South M	South N?	North F?	North G	Unassigned
Mellaart Level	Pre.XII	XII	X	IX	VIII	VII	VIb	VII/VI?		
Einkorn	x	x	x	x	x	x	x	x	x	x
Emmer	x	x	x	x	x	x	x	x	x	x
'New type' wheat	x	x	x	x	x	x	x	x	x	x
Free-threshing wheat	x	x	x	x	x	x	x	x	x	x
Naked barley	x	x	x	x	x	x	x	x	x	x
Lentil	x	x	x	x	x	x	x	x	x	x
Bitter vetch	x	x	x	x	x	x		x	x	x
Pea	x		x	x	x	x			x	
Chickpea	x			x					x	
Grass pea	x									
Hackberry	x	x	x	x	x	x			x	x
Pistacio/terebinth	x	x	x	x	x		x		x	
Clubrush tuber	x		x	x	x	x		x	x	
Acorn	x		x	x	x	x			x	
Almond	x								x	
Prunus L./*Amygdalus* L.	x	x	x	x	x				x	
Prunus sp.	x	x	x		x	x			x	
Bolboschoenus glaucus (Lam.)	x	x	x	x	x	x	x	x	x	x
Leguminosae , small wild	x	x	x	x	x	x	x		x	x
Aeluropus Trin.	x	x	x	x	x	x	x	x	x	
Polygonum aviculare aggregate	x	x	x	x	x	x	x	x	x	
Taeniatherum caput-medusae L.	x	x	x	x	x	x	x	x	x	
Carex L.	x	x	x	x	x	x	x		x	
Descurainia sophia (L.) Webb	x	x	x	x	x			x	x	
Sporobolus R. Br.	x	x	x	x	x			x	x	
Helianthemum Adans.	x	x	x	x	x				x	
Juncus L.	x	x	x		x	x			x	
Artemisia annua L. type	x			x	x	x		x	x	
Rumex L.	x			x	x	x			x	
Crypsis aculeata (L.) Aiton type	x		x	x	x				x	
Eragrostis N.M. Wolf	x		x		x				x	
number of samples	12	3	15	14	18	4	1	2	45	1
percentage of samples	10.43	2.61	13.04	12.17	15.65	3.48	0.87	1.74	39.13	0.87

Table 4.8 Distribution of the crop types and major wild taxa across the chronological phases

The observations made here correspond well with those from the previous archaeobotanical work on the same chronological sequence (Fairbairn *et al*. 2002, 2005a). The more or less identical spectrum of crop and wild taxa across this uniquely large assemblage deriving from different phases and buildings/spaces may point to temporal and spatial repetition in the plant-related practices which likely reflects continuity and stability of the plant procurement system, in turn reinforced by those very practices.

Chapter 5 Formation of the assemblage

The aim of this chapter is to identify as securely and specifically as possible the formation processes that gave rise to, and shaped the archaeobotanical assemblage under study. These processes include the collection or harvesting of plants in various habitats in the wider landscape, transportation of plant material to the settlement and various subsequent processes leading up to the final deposition and archaeological recovery. It is necessary to understand the nature of the various taphonomic 'filters' and, in particular, the ways in which they bias archaeobotanical content before further inferences can be made about the nature of plant-related activities and their social significance (Dennell 1972, 1974, 1976; Jones 1987; Hillman 1981, 1984; van der Veen 1992).

In palaeontology and geology, 'taphonomy' represents the transition of organic remains from the biosphere to the lithosphere (Grupe 2007). When investigating the taphonomy of, for example, vertebrate skeletons, the focus is on the processes leading to preservation and/or destruction, and how these are intertwined (Grupe 2007). In application to archaeology, the idea of taphonomy remains essentially the same: processes that resulted in the formation of an assemblage and that affected it up to the point of its recovery (e.g. Valamoti 2004; van der Veen 2007). This 'life-history' of plant remains is broadly defined as taphonomy in archaeobotany (Jones 1983; Jacomet and Kreuz 1999; Valamoti 2004; Jacomet 2007) and encompasses pre-depositional, depositional, and post-depositional processes (Clarke 1973) or, in other words, cultural and non-cultural factors (Schiffer 1976, 1987).

Whereas in palaeontology taphonomic investigations evaluate and 'unravel' the whole sequence of natural and anthropogenic processes an organism is subject to from its death until its recovery (Grupe 2007), in archaeobotany taphonomic considerations usually centre on human agency or 'cultural formation processes' (Schiffer 1987) affecting plants from the point of extraction from their growing habitat to their deposition and incorporation in archaeological sequences. In order to make justifiable inferences about the past agricultural and other plant-related activities at Çatalhöyük, this chapter investigates cultural formation processes (*sensu* Schiffer 1976, 1987) that are potentially relevant to the assemblage and are reflected in its composition. 'Non-cultural' (Schiffer 1987) or post-depositional (Clarke 1973) formation processes - events and processes of the natural environment that act upon

archaeological evidence (such as wind and water action, rodent activity and chemical weathering) - are of secondary importance for the assemblage formation and are not considered here.

The following sections discuss sources of charred plant material at Çatalhöyük and activities/events that affected it prior to the deposition, as well as methods used to disentangle the processes and determine their impact on the assemblage; the second part of the chapter presents results of the analysis.

5.1 Sources of charred material at Çatalhöyük

It has been noted that charred assemblages largely contain remains of harvested crops and their associated impurities (e.g. Knörzer 1971; Green 1982; M. Jones 1988; van der Veen 1992). As shown in Chapter 4, the majority of charred plant remains at Çatalhöyük derive from crops and hence from arable fields. Wild plants, however, may derive from a range of habitats – arable (as weeds) and non-arable (such as ruderal areas - edge of fields, roadsides, waste areas, or undisturbed - e.g. woodland, marshes). Crops were grown for food and/or fodder and by-products of crop processing were possibly used for fuel, fodder, bedding, thatching, temper and so on (Fairbairn *et al*. 2005a; Atalay and Hastorf 2005, 2006; Matthews 2005a; Tung 2005). Wild plants, including those occurring as arable weeds, may have been collected and used for food or medicinal purposes (Fairbairn *et al*. 2005a, 2007; Behre 2008), the useful parts potentially including seeds, fruits, nuts, tubers/roots, stems, flowers and leaves (Ertuğ-Yaraş 1997), and they may have also been used for building, matting and basketry, decoration and symbolic purposes (Fairbairn *et al*. 2005a, 2007; Matthews 2005a; Rosen 2005). Along with human consumption of plants, animals may have grazed on stubble and stands of wild plants around the site, or have been fed on crops, and they also represent plant consumers that potentially (indirectly) contributed to the assemblage. Ethnographic studies in Asia have described intensive use of animal dung as fuel and building material (see below, Section 5.2.3); archaeobotanical analyses informed by this work imply that animal dung was used in the same ways in the past, and that dung residues may have been incorporated in archaeological deposits, along with other fuels and discarded plant material (Miller 1984; Miller and Smart 1984; Charles 1998; Charles and Bogaard 2005; Crawford *et al*. 2005). Additionally, seeds of plants growing in and around the settlement could have been wind-

blown or brought in attached to people's clothing or animal fur and they could have potentially become charred; however it is not likely that their number and frequency (and type) would be comparable to those of the taxa 'regularly' present in the assemblage.

5.2 Processes involved in the formation of the assemblage

As discussed above, harvested crops and associated arable weeds, collected wild plants and animal dung are major sources of plant remains at Çatalhöyük. Each source implies specific human activities (i.e. cultural formation processes - Schiffer 1987) that created and shaped Çatalhöyük assemblage prior to the deposition (Dennell 1972: 149). Full and accurate understanding of the impact of these activities on the assemblage enables consideration of subsistence strategies and past human behaviour (e.g. Valamoti 2004; van der Veen 2007; Hald 2008).

5.2.1 Crop processing

It is widely acknowledged that the effects of various activities/processes on the assemblage are best represented in its composition (i.e. composition of individual samples combined) and hence the composition allows inferences about the relevant processes (e.g. Dennell 1972; Hillman 1981; Jones 1991; Fuller *et al*. 2005). Previous and current archaeobotanical work at the site has shown that the remains of crops (cereals and pulses) dominate the assemblage, with remains of hulled wheats (mainly emmer) being the most common (Helbaek 1964; Fairbairn *et al*. 2002, 2005a; Bogaard *et al*. in press/2013). Examination of the archaeobotanical composition of the samples selected for the present study (Ch. 4) also demonstrated that remains of crops are the most frequent, and of those attested, hulled wheats have been identified as the main crop category.

Crop material is likely to have been affected by processing for storage and consumption, and potentially also by subsequent uses of products and by-products of processing (Dennell 1974; Hillman 1984b; Jones 1984). For example, much of the evidence for cereal cultivation at Çatalhöyük comes from the charred remains of chaff, which are considered to have derived from cereal processing. Therefore, a full taphonomic study of cereal processing based on products/by-products present in the samples was carried out in order to establish which

processing stage(s) have affected the composition of the samples. As argued by Jones, this is best achieved by analyzing each individual sample, before combining samples and looking at site-level or regional patterning (Jones 1991).

Observation of present-day traditional agriculture in various parts of the world, particularly the systematic field-studies by Hillman (1981, 1984a, 1984b, 1985), Jones (1983, 1984, 1987), Peña-Chocarro (1996) and D'Andrea and Mitiku (2002), provide ethnographic models useful as a basis for exploring the impact of crop processing on archaeobotanical assemblages (e.g. van der Veen 1992; Reddy 2003; Valamoti 2004; Bogaard 2004a; Hald 2008). Given that the main aim of crop processing is to filter out unwanted components of crop harvest, Hillman and Jones suggest that the processing can be performed in only a few 'successful' ways using traditional methods determined by the physical properties of the plants/plant parts and the desired end products. They propose that, regardless of the particular cereal or pulse crop being cleaned and the tools used in the process, the major stages in post-harvest processing are: threshing, winnowing, coarse sieving and fine sieving. Presence/absence of these stages, and their sequence (e.g. prior to or post-storage of crops) may vary across regions and trough time, and can be determined by social choice or cultural tradition, economic conditions, available equipment and labour etc (D'Andrea and Mitiku 2002; Reddy 2003; Stevens 2003; Fuller and Stevens 2009). The ethnographic studies by Hillman (in Turkey) and Jones (in Greece) are here understood as potentially representative of the Mediterranean tradition(s), and their ethnoarchaeological models of crop processing appropriate for application to the assemblage under study.

In general, initial threshing breaks ears into spikelets (in hulled wheats) or releases grain from chaff (in free-threshing cereals and pulses); winnowing removes light parts (straw if present, light chaff, awns, light seeds); coarse sieving removes unthreshed ears, straw nodes, large weed heads/pods and seeds larger than crop grain/seed (spikelet in case of hulled wheats); and fine sieving removes heavy seeds smaller than crop grain/seed (Dennell 1974; Hillman 1981). In free-threshing cereals and pulses, these four stages result in isolation of a clean product (grain/seed) on the one hand, and a series of by-products of each stage on the other (Hillman 1985; Jones 1987, 1990). In hulled wheats, initial threshing breaks ears into individual spikelets (one or more grains enclosed by glumes) that require an additional threshing/dehusking sequence. From Hillman's (1981, 1984b) observations it appears that after coarse sieving, storage of hulled wheat spikelets (with accompanying weed seeds of a

similar or smaller size) is characteristic in areas with wet summers in Turkey (and perhaps in small farmsteads where large processing equipment is not available - Hillman 1984a: 9), while additional processing (i.e. dehusking) is done piecemeal, on a day-to-day basis. In arid areas of Turkey, grain released from chaff is stored. In contrast to this, D'Andrea and Mitiku (2002) documented storage of emmer *spikelets* in generally dry northern highlands of Ethiopia.

Spikelets are dehusked by pounding and then again winnowed (to remove light parts), coarse-sieved (to remove spikelets and straw nodes) and fine-sieved (to allow glume bases and seeds smaller than grain to pass through the sieve which retains the grain - Hillman 1981, 1984a). As opposed to these observations, experimental pounding of hulled wheat and subsequent separation of grains from glumes have suggested that mere winnowing after dehusking is sufficient for removing chaff (Küster 1984; Meurers-Balke and Lüning 1992), which would imply that pre-dehusking stages of processing successfully remove large and heavy (non-winnowable) glume and straw material. In reference to the present study, based on the ethnographic and experimental evidence, it appears that archaeobotanical samples dominated by hulled wheat glume bases could potentially represent by-product of post-dehusking winnowing or fine sieving or a combination of the two stages. Bogaard (2004a: Appendix; also, D'Andrea and Mitiku 2002) has experimentally tested 'winnowability' of different hulled wheat glume bases and demonstrated that einkorn and emmer glume bases could be winnowed off, particularly einkorn glume material, while emmer or einkorn/emmer maslin would probably require fine-sieving. In sum, it is possible that cleaning of pounded hulled wheat spikelets was practiced by solely winnowing or fine sieving, or both.

Hand-sorting of grain is also required to remove contaminants inseparable from grain by sieving, and re-processing is sometimes necessary (Hillman 1984b). For (human) consumption, grain is used whole or ground into flour (D'Andrea and Mitiku 2002: 200), or coarse-ground into 'bulgur'- cracked grain (Ertuğ 2004a). Hillman (1984b) documented an alternative, 'Karslı sequence' of bulgur preparation in which spikelets from storage or straight from winnowing and coarse-sieving are milled, resulting in grain separated from chaff and broken into fragments, and mixed with 'light' and 'heavy' chaff and weed seeds. This stage is followed by winnowing, fine-sieving (which here separates cracked grain – 'grits' from unbroken grains, large pieces of chaff and large weed seeds) and hand-sorting, as in 'normal' post-dehusking sequence.

In processing of harvested crops, weeds, chaff and straw (by-products) are separated from grain (product) by variety of techniques. Each stage in the sequence produces different albeit predictable combinations of crop parts and weeds seeds – and these are potentially identifiable in archaeological material (Hillman 1981; Jones 1987). The results of ethnographic studies have been compared to archaeobotanical material in order to identify the products and by-products of crop processing based on the botanical composition of archaeological samples (Hillman 1981, 1984a, 1984b; Jones 1983, 1984). Jones analysed the composition of modern samples of by-products and products of free-threshing wheat and hulled six-row barley processing from Amorgos, Greece (Jones 1987, 1990) and provided quantitative data for components removed by winnowing, coarse sieving and fine-sieving. She compared modern data from Amorgos to the archaeological data from storage contexts of Assiros using discriminant analysis, and showed that the analysis of the composition of ethnographically collected samples of crop products and by-products offers a good basis for distinguishing between crop products and by-products in archaeobotanical record (Jones 1987: 311). Based on these observations, she subsequently developed two distinct methods for determining crop processing stages of archaeobotanical samples: a 'crop-based' method uses relative proportions of different crop parts that are most likely to survive charring (grain and rachis) and weed seeds (Jones 1990); a 'weed-based' method relies on the physical characteristics of weed seeds in relation to crop processing stages (Jones 1984, 1987).

5.2.1.1 **Crop-based method of crop-processing analysis**

The 'crop-based' approach adopted here first considers ratios of grain to chaff (glume bases or rachis internodes) in unprocessed cereal ears of relevant species, and compares them with ratios of the same plant parts in archaeobotanical samples. This method can potentially distinguish products and by-products as well as identify mixing of processing stages in the samples (Bogaard 2004a). The method is limited to analysis of cereal content, since for example flax and pulse 'chaff' (pod fragments, stems) are rarely preserved by charring (Jones 1987; Hald 2008). Furthermore, only the remains of cereals with the same processing requirements (hulled wheat type versus free-threshing cereal type - Hillman 1984a, 1985) can be considered together; calculation of ratios for each cereal 'group' on a sample by sample basis helps identify whether they are represented as by-product or product of processing (Jones 1991; van der Veen 1992; van der Veen and Jones 2006).

Unprocessed ears of cereals have species-specific grain to chaff ratios. In the case of emmer, the grain:glume base ratio is 1:1 because there is one grain per glume base (i.e. two grains per spikelet fork), with the exception of the terminal spikelet, which contains one grain. The same ratio applies to two-seeded einkorn and, apparently, 'new type' wheat (Jones *et al*. 2000b: 135-136). In one-seeded einkorn, the grain:glume basis ratio is 1:2 because a single grain is enclosed by two glume bases. Grain:rachis internode ratios in free-threshing wheat tend towards 3:1 on average (Jones 1990: 92); in barley, ratios are 1:1 for two-row and 3:1 for six-row varieties (Ewert and Wiebe 1946; Jones 1990: 92; Hald 2008). These values were used as a basis for the initial classification of Çatalhöyük samples as potential products or by-products of crop processing (Section 5.3.1).

Following Jones' model (1990; cf. Dennell 1974), a further step in the crop-based analysis is to calculate relative proportions of grain, chaff and weed seed and, by comparing with ethnographic data, to determine their potential status as by-products from different stages of processing or as final products (Jones 1990: 92-93). Jones' ethnographic study was carried out on free-threshing wheat and hulled barley, which at Amorgos were often grown and processed together. The approach can be adapted to hulled wheats (substituting glume bases for rachis internodes), but proportions of weed seed present at different stages of hulled wheat processing remain unknown: neither Hillman's ethnographic account of processing of hulled wheats in Turkey (1984a, 1984b) nor subsequent ethnographic studies (e.g. Peña-Choccaro 1999; D'Andrea and Mitiku 2002) have provided quantitative data for crop and weed components of by-products and products. It can be hypothesised that winnowing followed by coarse and/or fine sieving prior to dehusking would remove most weed seeds (see below), meaning that cleaning of pounded spikelets would produce a by-product made up mostly of chaff and not much weed material (Bogaard 2004a). Thus, application of the method to hulled wheats may reveal informative trends in weed content and highlight 'anomalous' samples - e.g. with much higher 'potential weed' content than expected, perhaps representing plant sources additional to crop processing *per se*.

5.2.1.2 **Weed-based method of crop-processing analysis**

Jones (1984) carried out weed-based analysis of samples of by-products and products of processing free-threshing wheat and pulses, collected in an ethnographic study of traditional farming practice on the Greek island of Amorgos. The analysis revealed that weed seeds alone

provide a (sufficient) basis for discriminating between different crop products and by-products, and that the use of other variables, such as ratio of crop to weed seeds (the 'crop-based' method) could improve the results (Jones 1987: 312). The ethnographic model she developed relies on the actual weed species encountered in modern samples and their association with the four main crop processing stages (winnowing, coarse sieving, fine sieving, and fine sieve product). Because of high geographical and temporal variation in weed taxa, the range of species found in ethnographical samples would not be the same as those found in archaeological samples (e.g Holzner and Numata 1982; Jones 1984; M. Jones 1988); therefore, instead of individual *species*, for archaeological application of the method Jones uses weed seed *characteristics* which are most relevant to crop processing (Jones 1984, 1987): 'aerodynamic' properties (density/weight, shape and presence/absence of 'wings', hairs etc) which are relevant to winnowing; the tendency of seeds to remain in 'heads' (spikes, clusters, capsules, pods) after threshing, which means they would be retained in the coarse sieve ('free' seeds pass through); and the size of seeds, relative to fine sieve mesh ('large' seeds, i.e. seeds of a similar size to the crop seed/grain being cleaned, are retained in the fine sieve). Based on the relevant physical attributes, Jones classifies weed seeds as: big, headed, heavy (BHH); big, free, heavy (BFH); small, headed, heavy (SHH); small, free, heavy (SFH); small, headed, light (SHL) and small, free, light (SFL). The validity of the classification was tested on weed species from modern (Amorgos) samples using discriminant analysis; the species were grouped into six respective categories/weed types, which were treated as discriminating variables. The discriminant functions, extracted from the proportions of the established weed seed types in ethnoarchaeological samples, reclassified the samples into the four original processing groups with high accuracy (84% correct).

The results also showed which categories of weed seeds can be expected as by-products from different stages of crop processing and which category would remain with final crop product. Winnowing tends to remove SFL type seeds, coarse sieving 'headed' seeds (BHH, SHH, SHL) and fine sieving SFH type of seeds, while BFH type weed seeds tend to remain with the (fine sieve) product, to be removed by hand-cleaning (Jones 1984: Fig. 6). Because the method draws upon proportions of categories of weed seeds (according to their different characteristics) and not crop parts, it is more widely applicable than calculations of the relative quantities of grain, chaff and weed (Jones 1987).

The ethnographic models of crop processing have been applied to various charred archaeobotanical assemblages in order to identify crop processing products and by-products represented in the samples (e.g. Jones 1987; Charles and Bogaard 2001, 2005; Bogaard 2004a, 2012; Valamoti 2004; Hald 2008). The archaeological assemblages studied in this way comprised different crops (pulses, free-threshing cereals, hulled wheats) that to some extent require different processing stages (e.g. hulled wheats require additional dehusking) and have different components of by-products and products (chaff of free-threshing cereals is removed in winnowing and coarse sieving, while hulled wheats are generally stored in spikelet and hence glume bases more likely to become charred - Hillman 1981, 1984b), or certain crop components are not preserved (e.g. for flax, the seed to 'chaff' ratio is not obtainable - Hald 2008). The application of both models (crop-based and weed-based) provided a highly robust means of interpreting the samples in terms of their association with crop processing stage(s). Therefore, both methods were used in examination of the Çatalhöyük assemblage, in order to obtain results from two independent but complementary approaches. Also, despite the fact that conditions under which crop processing takes place (e.g. strength of breeze in which winnowing is done), tools used (winnowing with fork or basket), the thoroughness of winnowing and sieving, the range of crop weeds and so on vary greatly in space and time (Jones 1984; Peña-Choccaro 1999), and they are not (immediately) visible in archaeobotanical samples, previous crop processing analysis show that it is indeed possible to identify similarities between samples/groups of samples comparable to the results of ethnographic studies.

5.2.2 **Harvesting methods**

Hillman (1981, 1984a) documents two general cereal harvesting methods observed in Turkey: harvesting of cereals by reaping (with a sickle, low or high on the straw), which results in a mixture of cereal ears, straw and weeds, and by uprooting (by hand or with blunt long-handled sickle used as a lever), which yields a combination of ears, straw, culm bases of cereals, and weeds.

In uprooted cereals, culm bases are usually chopped off right after harvest, while the crop is drying in the field (or barns), which suggests that they would not normally enter 'domestic' contexts (Hillman 1981). In the northern highlands of Ethiopia, where emmer is still grown and traditional cultivation methods used, emmer stems are cut about 5 cm above the ground

with a sickle, while uprooting using a sickle is also sometimes practiced (D'Andrea and Mitiku 2002).

Ear-harvesting/ear-plucking is an alternative method, recorded in Spain (Peña-Chocarro 1996, 1999) and is suitable for harvesting hulled wheats just underneath the seed head; since the basal rachis of the ear is fragile (Ibáñez *et al*. 2001), it remains attached to the straw (Hillman 1981, 1985). The action can be carried out by hand or with a tool, e.g. *mesorias* (composed of two wooden sticks attached with a string at one end) which is still used for harvesting spelt and emmer wheat in the region of Asturias, northern Spain (Peña-Chocarro 1999; Ibáñez *et al*. 2001; pers. observation). Similar to this is stripping grains off a stem, in which case only ripe grains/spikelets come off, while unripe grain and basal spikelets stay on the stem (P. Anderson, pers. comm.). Ear-harvesting of free-threshing cereals would not be performed by snapping off the ear at basal rachis, since the rachis is tough, but cutting high on the straw could be an equivalent to ear-harvesting. However, the uneven ripening of free-threshing grain along the ear (i.e. top spikelets are the first to become ripe) and scattering of ripe grains (causing yield loss) may require harvesting of still unripe free-threshing plant by cutting the stem close to the ground, or uprooting (Cappers and Raemaekers 2008: 389), though harvesting of (not fully ripe) barley high on the culm has been archaeologically documented at Neolithic Hornstaad Hörnle IA in Germany (Maier 1999: 92).

Different harvesting methods primarily affect composition of archaeobotanical weed assemblages (the range of weed species and their abundance), though crop content may vary to some extent in terms of plant parts represented. For example, Hillman (1981) has suggested that the height at which cereals were sickle-harvested in the past can be assessed by the number of culm nodes present in archaeobotanical samples – the more straw (resulting from harvesting low), the higher the number of culm nodes (which happen to be parts of the straw most likely to survive charring, yet not as well as glume bases and grain; Boardman and Jones 1990). This does not imply that absence of cereal culm nodes from the archaeobotanical record is evidence of ear-harvesting; on the other hand, absence of basal rachis internodes of hulled cereals may indicate ear-harvesting (Hillman 1981, 1985; Peña-Chocarro 1999).

Much more weed material tends to be collected by sickle- than by ear-harvesting (Hillman 1981), and ear-harvesting selects the seeds of climbing weeds (such as black bindweed, *Polygonum convolvulus* and cleavers, *Galium aparine* L.; Bogaard 2004a). However, the

composition of weeds accompanying sickle-harvested crops can vary greatly depending on the harvesting height. The lowest maximum weed height represented in the archaeobotanical samples can be used to estimate the maximum height at which crops were cut (Bogaard 2004a, 2012; Hald 2008).

Establishing the *actual* weed status of the *potential* weed taxa recovered from archaeological sites offers an opportunity for consideration of harvesting regimes based on the plant characteristics, such as maximum plant height of the weed species (to assess high- or low-harvesting in case of sickle-harvesting) and growth habits (climbing/non-climbing, to assess possibility of ear-harvesting). Another possible approach using crop processing analysis is to examine the amount of weed seeds relative to crop material in the samples (Jones 1990). The study by G. Jones (1984) of modern crop processing sequence on Amorgos has also provided data on the weed and crop content of sickle-harvested free-threshing cereals; these data can be directly compared with the archaeobotanical results for free-threshing cereals to assess potential derivation from sickle harvesting (Bogaard 2004a, 2012).

5.2.3 **Use of animal dung as fuel**

Ethnographic observations in parts of south-west Asia and other semi-arid zones have shown that animal dung has been and still represents a major source of fuel in rural areas (Miller 1984, Ertuğ-Yaraş 1997; Charles 1998; Anderson and Ertuğ-Yaraş 1998; Reddy 1999); in Europe, dung was collected and used in some northern regions (e.g. Ireland, Scotland, Denmark) up until 19th century (Fenton 1985). The use of dung as fuel is generally practised in treeless, forest-depleted zones (Anderson and Ertuğ-Yaraş 1998; Reddy 1999); however, dung has often been a preferred fuel even where other sources exist due to its immediate availability and burning properties, which can be controlled/improved by adding various vegetal materials (Anderson and Ertuğ-Yaraş 1998; Charles 1998), or because other types of fuel were reserved for members of the society with higher social status (Fenton 1985: 96). Dung is collected from stalls and grazing areas and around settlements, and made into flat cakes (discs), sometimes adding temper such as straw, chaff and other dry vegetation, and water (if dry) to make it soft and easier to work (sheep and goat pellets are sometimes added to cow dung as additional temper - Fenton 1985; Reddy 1999). Dung cakes are left to dry in the sun, on the ground, on rooftops of houses or plastered against house walls; once dried, they are stored for future use (Ertuğ-Yaraş 1997; Reddy 1999).

Ethnographic and experimental studies have demonstrated the potential of different seed types and plant parts (e.g. cereal grain and chaff, pieces of straw and variety of wild/weed seed) to pass through the digestive system of animals and, depending on the effect of digestive processes of livestock, survive in an (microscopically) identifiable form (Miller 1984; Miller and Smart 1984; Russi *et al*. 1992; Gardener *et al*. 1993; Charles 1998; Valamoti and Charles 2005; Wallace 2007). In modern experiments, selected plant material was fed to animals and the resulting dung collected and studied for the effects of animal digestion on the botanical material. The experimental results suggest that many small-sized (wild) seeds do survive digestion, those with hard testa (seed-coat) in particular (Russi *et al*. 1992; Valamoti and Charles 2005; Wallace 2007; Wallace and Charles in press). The survivability of cereal parts is variable; in general, it appears that both cereal chaff and grain have a very low survival rate, though chaff may have a greater chance of surviving in an identifiable form than grain (Valamoti and Charles 2005; Wallace 2007). Experimental work has also revealed that plant material present in animal dung survives subsequent charring and thus produces remains preserved in a state similar to charred archaeobotanical material (Bottema 1984; Valamoti and Charles 2005; Wallace 2007). This has direct implications for the formation of archaeobotanical assemblages since, if (regularly) burnt, animal dung could represent a major/significant source of (identifiable) charred plant remains on archaeological sites (Miller 1984; Miller and Smart 1984; Charles 1998).

Information obtained from archaeological studies of dung residues have proved very useful when addressing questions such as ancient plant and animal husbandry regimes and, more specifically, livestock diet (i.e. feeding patterns), reconstruction of grazed vegetation, seasonality of plant-related activities such as dung collection and dung cake manufacture, building practices and so on (e.g. Akeret and Jacomet 1997; Charles 1998; Karg 1998, Reddy 1999; Charles and Bogaard 2001, 2005; Valamoti 2004, 2007; Matthews 2005a, 2010; Linseele *et al*. 2009).

There are various factors that affect/limit the accuracy with which archaeological plant material can be assigned a dung origin. Seeds and other plant material present in dung may come from a range of sources (e.g. grazed material, crop processing (by-)products, wild plant material collected for fodder) and are affected by animal consumption (i.e. chewing) and digestion in different ways (Charles 1998; Anderson and Ertuğ-Yaraş 1998; Charles and Bogaard 2005); also, fodder can be in some way prepared prior to being fed to animals (to

ease digestion; Charles and Bogaard 2005, 2010). Experiments have shown that some physical properties of plant material (e.g. shape, weight, 'hardiness') also have an impact on the rate of preservation through digestion; for example, small seed size and/or presence of hard seed coat enhance survival in the digestive process (Anderson and Ertuğ-Yaraş 1998; Wallace 2007; Wallace and Charles in press). Manufacture of dung cakes for use as fuel may involve intentional addition of plant material (e.g. crop processing by-products) as temper, or accidentally - in drying and packing, and this further complicates reconstruction of sources of archaeobotanical remains (Anderson and Ertuğ-Yaraş 1998; Reddy 1999). Finally, burning of dung in hearths and ovens, together with various other materials used as fuel (e.g. plant processing by-products) or accidentally burnt (e.g. food spoilage) makes it very difficult to trace the dung-originated components of the charred assemblages (Bottema 1984; Miller 1984).

On the basis of ethnoarchaeological investigations, Miller (1984) and Miller and Smart (1984) have offered several criteria for identification (or, more accurately, confirmation of presence) of dung-derived charred remains in archaeobotanical assemblages: scarcity of woody plants (hence, reliance on animal dung as fuel), presence of livestock producing dung, presence of burned dung pellets in the assemblage, presence of seeds of plants potentially eaten by livestock, and recovery of samples containing dung pellets and/or 'relevant' seeds from hearth contexts. Charles (1998) has questioned the reliability/usefulness of these criteria: while they do help explain and identify potential use of dung as fuel, they do not identify dung as the source of charred plant remains nor help distinguish between dung-derived material and material arriving from other sources. Charles (1998) suggested criteria for the specific identification of archaeobotanical material resulting from burning of dung: the biology and ecology of non-crop species (indicating when and where these taxa were growing, to potentially exclude harvesting with crops), the behavior of the non-crop seeds in relation to crop processing (showing whether they derived from the same stages of crop processing as associated crop material), and the relative proportions of crop species and plant parts – grain and chaff (pointing to preparation and use for human or animal consumption). Application of one of Miller and Smart's criteria (presence of burned dung pellets in the assemblage and, specifically, the observation of *seeds in dung* - Charles 1998) and, more suitable, Charles's criteria in the analysis of the composition of plant material from two Bronze Age sites (Abu Salabikh in Iraq and Tell Brak in Syria) brought to light the potential for distinguishing between archaeobotanical material from different sources/activities (i.e. crop processing and

use of dung), that is, for identification of different formation processes (Charles 1998; Charles and Bogaard 2001). Subsequent studies that employed these criteria have confirmed their pertinence to investigations of, for example, animal husbandry (diet and feeding regimes), use of crop-products and by-products, past fuel use etc (e.g. Valamoti 2004; Charles and Bogaard 2005, 2010; Hald 2008).

The four main criteria for identifying dung-derived charred plant material in archaeobotanical samples set out by Charles (1998) were applied to the Çatalhöyük dataset (see below). Additionally, observations from the relevant experimental work (Valamoti and Charles 2005; Wallace 2007; Wallace and Charles in press) were drawn upon in separation of potential residues of animal diet from the results of dung-fuel preparation or post-depositional mixing in order to refine understanding of the role of dung-derived material in the formation of the archaeobotanical assemblage.

5.2.4 **Charring (carbonization) and the biases imposed**

Charring preserves plant material after it has been subjected to heat, transforming the plant parts (particularly the dense or woody parts) to almost pure carbon (Jacomet and Kreuz 1999; Jacomet 2007). Charred plant material can be recovered from any archaeological site where fires have burnt or to which fire waste has been brought (*ibid*). Charring may occur in a number of routine activities, including parching of hulled wheat spikelets to ease dehusking, singeing of ears to remove awns, discard of plant processing and plant consumption by-products in domestic fires, accidental burning of food during preparation, removal of infested/diseased seed and cleaning out of storage pits using fire (Dennell 1972, 1976; Hillman 1981, 1984b; Peña-Chocarro 1996; van der Veen 2007). Large amounts of charred plant material (e.g. crop products) may indicate presence of major fires resulting in destruction of rooms or whole structures (Bogaard *et al*. 2005a; van der Veen 2007). As a result, both plant products routinely used as fuel (wood, by-products of plant processing and consumption, plant parts in dung) and accidentally burnt plant parts can be preserved and deposited in archaeological contexts, potentially representing different activities/events. This implies that human agency is the main factor deciding if and what kind of material will come in contact with fire (Valamoti 2004) introducing a bias into the 'original' (pre-charring) plant record, as the human uses of plants dictate their chances of preservation (e.g. fruits consumed raw or plants of which 'green' parts are often not visible in charred assemblages - Dennell

1976). As a result, charred plant assemblages usually consist of remains of crops and their weeds and, to a lesser extent, wild food plants (e.g. Dennell 1972; Renfrew 1973; Hillman 1981, 1984; M. Jones 1988; van der Veen 2007). They are, therefore, highly suitable for the reconstruction of agricultural practices (e.g. van der Veen 1992, 2007).

In addition to human day-to-day/routine or casual activities biasing charred plant assemblages, charring itself imposes a bias due to the complexity of charring conditions on the one hand, and variable plant 'response' to charring on the other. Charring experiments have suggested that temperature and time have the most significant effects on seeds of both crops and weeds (e.g. Wilson 1984; Kislev and Rosenzweig 1991; Boardman and Jones 1990; P. Wright 2003; Braadbaart 2004, 2008; Märkle and Rösch 2008). The most useful observations relevant to the present study are results provided by Boardman and Jones (1990). In these charring experiments, they demonstrated that, under a range of burning conditions, hulled wheat grain survives as well as, or better than glume bases, while hulled wheat glume bases survive better than rachis of free-threshing cereals. It appears that, under a range of different burning conditions (in terms of oxygen reduction, temperature and time) straw, light chaff and rachis fragments would disintegrate rapidly; grains exhibit the widest range of survival conditions and would frequently be preserved, while glume bases fall into 'intermediate' position (Boardman and Jones 1990). In conclusion, the first crop components lost through charring are those which are rarely represented archaeologically, and which are characteristic of early crop processing stages (i.e. straw and free-threshing cereal rachis). This means that the chaff of free-threshing cereals (rachis segments) will tend to be under-represented compared to hulled wheat chaff (glume bases) and therefore, the two types of cereal should not be treated together in the (numerical) analysis. Furthermore, destruction of grain in conditions where other parts are preserved does not seem likely and predominance of for example, glume bases would without doubt be a result of human activity (i.e. cleaning of grain); however, absence of glume bases does not necessarily imply human interference, as grain survives charring better (Wilson 1984; Boardman and Jones 1990). It has also been noted that hulled wheat grain 'state' after charring is better than that of naked wheat (Braadbaart 2008), which is relevant to the samples containing combination of hulled wheat grain and free-threshing grain (in addition to different crop processing routes, see above).

Experimental charring of seeds of different weed and wild species has demonstrated their differential preservation under different charring regimes according to their size, shape,

structure and moisture/chemical content, as well as the duration of exposure to heat, temperature, and oxidation versus reduction atmosphere (Wilson 1984; P. Wright 2003). For instance, oily seeds are likely to burn most readily, and seeds with high moisture content are more likely to explode in heating than dry ones (Wilson 1984). The different rates of survival for various species and their plant parts may bias the archaeobotanical record, and it has therefore been argued that "the composition of a carbonised [charred] fossil assemblage is no indication of its composition before carbonisation [charring]" (Wilson 1984: 205). However, the same biases apply when comparing archaeobotanical samples and they are predictable. For example, based on the results of the charring experiments it can be assumed that plant parts most likely to survive charring are those that are the hardiest or more robust than others (e.g. seeds, culm nodes, nut shells, 'hard' chaff - glume bases, rachis segments). Rather than consideration of individual species or types of remains, consideration of *categories* of archaeobotanically represented taxa classified according to various plant characteristics (ecological, phytosociological, morphological, chemical etc), is one potential way of overcoming the fragmentary nature of charred archaeobotanical assemblages in an attempt at reconstruction of plant use in the past (Jones 2002).

5.3 Crop processing stages represented in the Çatalhöyük samples

As discussed in previous sections, charred plant remains arrive on archaeological sites by various routes and from a range of sources; a number of processes/activities affect plant material at archaeological sites and are potentially identifiable through analysis of the composition of archaeobotanical assemblages.

Processing of crops for storage and consumption is a major factor influencing the composition of charred plant assemblages. Initial examination of the Çatalhöyük dataset (Ch. 4) showed that all selected samples contain crops and potential arable weeds, and are therefore considered suitable for crop processing analysis.

5.3.1 Crop processing analysis using the crop-based method

One way of estimating crop processing stage of the samples is to calculate the ratios of grain to chaff for different crops (Section 5.2.1.1). Due to the predominance of hulled wheats (i.e.

einkorn, emmer and 'new type' wheat) over those of free-threshing cereals (free-threshing wheat and barley) and pulses in the crop content of the majority of samples (Section 4.3.1), the hulled wheat component was the primary focus of this approach. All selected samples (i.e. hulled wheat, pulse and 'mixed-crop' - Section 4.3.1) were included in the crop processing analysis. Mixed crop samples were examined in order to gain insight into the stage(s) of crop processing potentially combined. Mixing of different stages of processing of the same crop/crop type may be difficult to detect; on the other hand, mixing of different crop types (e.g. free-threshing and hulled cereals) not likely to be grown and processed together can be readily identified (Charles 1998; Charles and Bogaard 2001: 310).

5.3.1.1 **Hulled wheat**

The ratios of grain to glume bases were calculated for hulled wheat material on a sample-by-sample basis using the 'corrected' counts for the grain and glume bases (i.e. after conducting proportional re-assignment of indeterminate cereal grain - see Section 3.6.3). A combination of one- and two-seeded hulled wheat types occurs in the Çatalhöyük assemblage (Section 4.3), hence the grain:chaff ratio for whole spikelets could range from 0.5 (1 grain per 2 glume bases) to 1.0 (2 grains per two glume bases). Given the potential for preferential loss of chaff due to charring bias (Boardman and Jones 1990), however, the ratios of grain to chaff expected in concentrations of whole spikelets would exceed 1.0. Moreover, there is a preponderance of two-grained hulled wheat material in the assemblage - emmer, 'new type' wheat and two-seeded einkorn. For both of these reasons, the expected/archaeological ratio of grain:glume bases for an 'unprocessed' spikelet was estimated as a range of around 0.5 to 2.0 - varying between 'perfect' preservation of single-grained spikelets, with one grain for every two glume bases, to biased preservation of two-seeded spikelets, with two grains for each glume base.

Table 5.1 shows the overall grain:chaff ratios for the 94 samples; two groups of samples were recognised:

a) Thirteen 'spikelet samples' (14%), with a relatively high ratio of hulled wheat grains to glume bases (i.e. within the 'spikelet' range of 0.5-2.0), potentially represent semi-clean/stored product. Three of the samples have grain:chaff ratios remarkably higher than expected and perhaps indicate cleaned product, though their crop content is not dominated by hulled wheat (i.e. hulled wheat ≤70% of the total crop; Section 4.3.3) -

two samples are ‘mixed’, one is pulse-rich (Table 5.1). Given that grain tends to survive charring better than chaff (Boardman and Jones 1990), these three samples could also be considered potential ‘spikelet samples’. The crop content of further eight spikelet samples is largely composed of hulled wheat while two spikelet samples appear mixed (they contain similar proportions of the three crop groups).

b) In the remaining 81 samples (86%), the grain:chaff ratio is (much) lower than projected for potential spikelet samples (<0.5); the ‘glume-base’ samples could represent residues from cleaning (winnowing and/or sieving) of pounded spikelets (Hillman 1981, 1984b). The majority (76) of them are dominated by hulled wheat remains; five were classified as mixed-crop (4) and pulse samples (1).

As explained in Section 5.2.1.1, a further step in the crop-based approach is to consider proportions of grain, rachis internodes and wild/weed seeds in the samples and, based on the ethnoarchaeological work of Jones (1990), to determine their potential status as by-products from different stages of processing, or as final products. This approach, originally based on observation of free-threshing cereal processing, can be adapted to hulled wheats by substituting glume bases for rachis internodes. Since the proportions of weed seed expected at different stages of hulled wheat processing is unknown (i.e. no modern studies similar to Jones’s have been carried out for hulled wheats), this step is essentially exploratory; nonetheless, it may reveal informative trends in weed content and highlight ‘anomalous’ samples.

The 65 wild/weed taxa included in the analysis are listed in Table 5.2. Taxa represented by silicified remains (*Boraginaceae, Eleocharis, Lemna*) were left out of the analysis due to their likely entry into the assemblage via route(s) separate to the charred crop remains; the 22 indeterminate wild/weed taxa were also excluded. Figure 5.1a shows the distribution of samples based on the proportions of hulled wheat grain, hulled wheat glume bases and potential weed taxa in the ‘hulled wheat’ samples only (i.e. 84 samples with ≥70% hulled wheat in the total crop content). As Jones (1990) has pointed out, triangular plots like this one should not be used to explore the processing stage of samples containing a mixture of hulled wheat and free-threshing cereal remains, because the processing sequence and resulting products/by-products are different for the two crop groups, and the association of weed seeds with one or the other group cannot be determined. Here, the wild/weed component of the hulled wheat samples is regarded as potentially accompanying hulled wheats in cultivated

fields. The vast majority of hulled wheat samples contain a high proportion of glume bases and not much grain or weed material (as observed earlier, Section 4.3.1). The triangular plot in Figure 5.1b shows hulled wheat samples coded according to their grain:glume base ratio classification (spikelet *vs.* glume base samples). The samples concentrated towards the 'glume

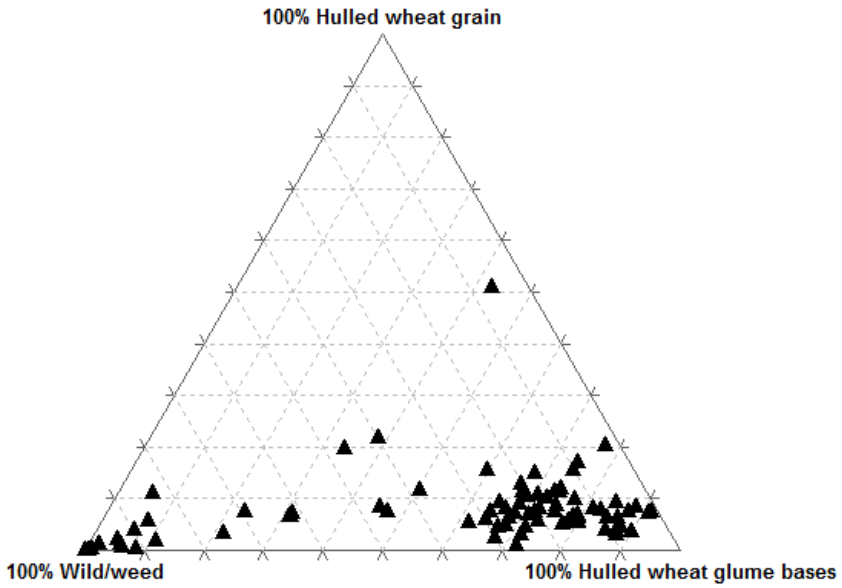


Figure 5.1a Distribution of the 84 hulled wheat samples based on the proportions of hulled wheat grain, hulled wheat glume bases and potential weed taxa (▲- samples)

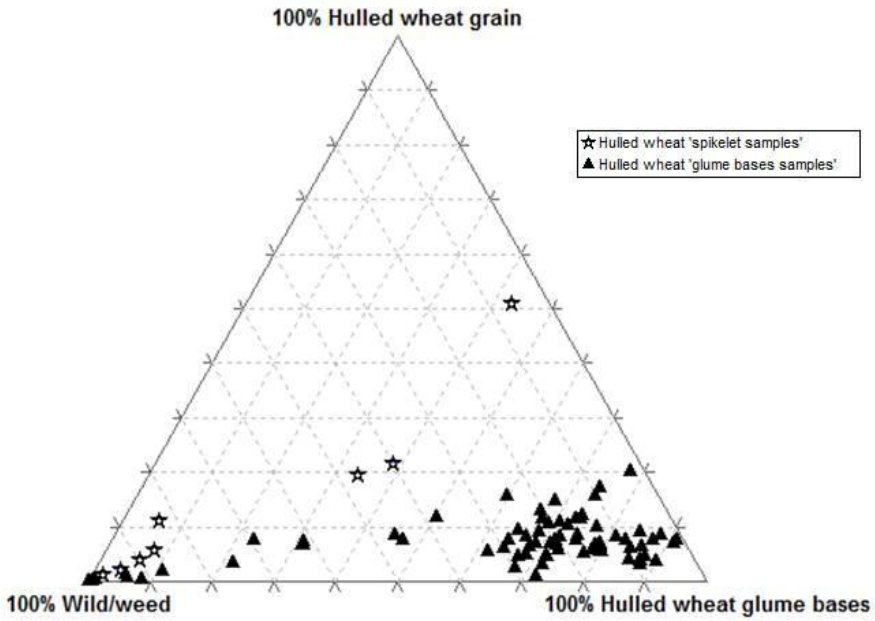


Figure 5.1b Distribution of the hulled wheat samples coded by their grain:glume bases ratio classification (spikelet and glume bases samples)

base' corner of the plot could be considered typical winnowing and/or fine sieving hulled wheat by-products. In contrast, the samples concentrated towards the weed corner of the plot contain notably high proportions of weeds (around 70% or more) and very little hulled wheat material. Among these, ten are mainly composed of *Descurainia sophia* seeds (Table 5.1; Fig. 5.1c), which have been attested at the site as a collected and stored resource (Bogaard *et al*. 2005a, 2009; Fairbairn *et al*. 2007). The ten samples have been considered 'anomalous' due to the very high 'weed' content which is not likely to represent arable weeds in these cases. Five of these were previously classified as spikelet samples. Overall, the *Descurainia*-rich samples appear to represent mixtures of crop (by-)products and collected *Descurainia*.

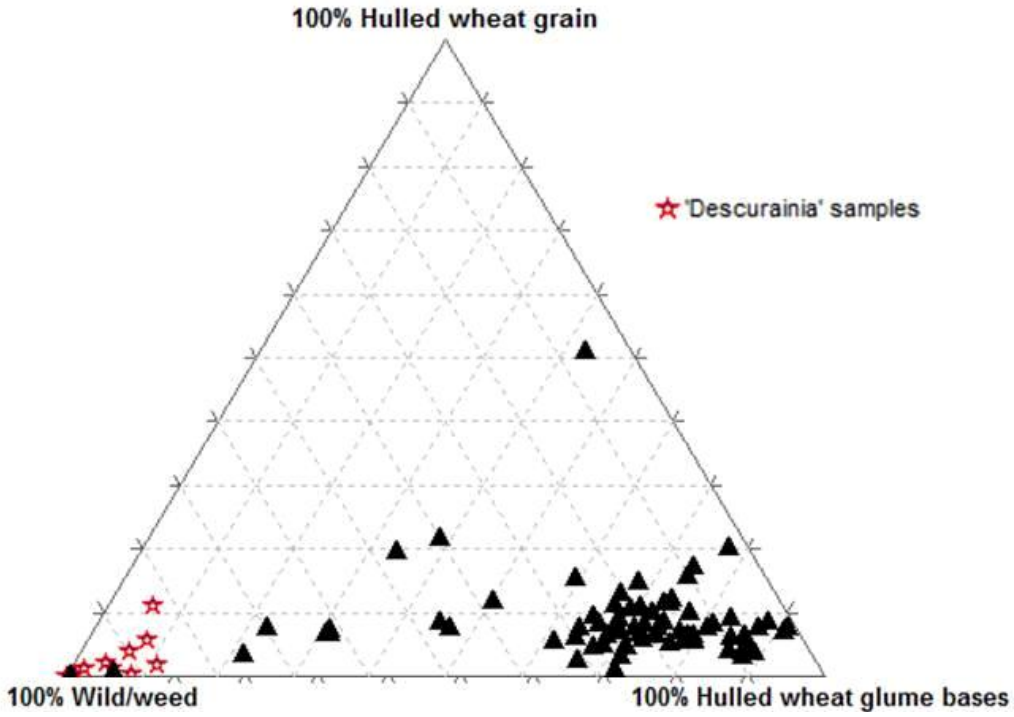


Figure 5.1c Distribution of the ten *Descurainia*(/hulled wheat) samples

5.3.1.2 **Free-threshing cereals**

Free-threshing cereals (bread wheat and naked barley) constitute a minor proportion of the overall crop content and are not predominant in any of the samples. Nevertheless, it was considered useful to explore the free-threshing component in terms of plant part representation as an aid to investigation of the origin of free-threshing cereal material and to possible identification of the processing stage(s) represented by the 'mixed crop' samples.

Since the specific association of any/all crop types and wild/weed flora in the mixed crop samples cannot be assumed (unlike the weed content of the hulled wheat-dominated samples, see above), relative proportions of grain, chaff and weed seeds cannot be used to compare the Çatalhöyük samples to the ethnobotanical samples from Amorgos (Jones 1990); instead, as suggested by Jones (1990) for mixed crop samples, free-threshing cereal grain to chaff (rachis internodes) ratios can be used. The free-threshing cereals observed in the Amorgos study were six-row barley, bread and macaroni wheat, all of which were grown together as a mixed or 'maslin' crop; they all have an 'unprocessed' grain:rachis ratio of *c*. 3:1 (i.e. three grains per rachis internode). Based on the rachis morphology, free-threshing wheat in the Çatalhöyük samples was identified as hexaploid - bread wheat - which has an average of three grains per rachis internode in unthreshed ears, thus the unprocessed ratio is 3:1 (Jones 1990; Jacomet 2006). The Çatalhöyük samples contain both six- and two-row barley rachis segments, suggesting that their grain:rachis ratios would, if anything, tend to be lower than those in the Amorgos study: the grain:rachis ratio in unthreshed two-row barley is 1:1, in six-row 3:1 (Jacomet 2006). However, the differential preservation potential in charring of free threshing cereal grain and rachis tends to bias the archaeobotanical material in favour of grain (Boardman and Jones 1990). Therefore, no attempt was made to 'correct' the Çatalhöyük figures to take account of two-row barley, and the grain:rachis ratio of 3:1 (3.0) is used as a threshold in the comparisons.

Using the published data (Jones 1990: Table 6) grain:rachis ratios for Amorgos free-threshing cereals were calculated for the modern samples that contained ≥30 items (and were thus considered reasonably representative) (Table 5.3a-c). As anticipated, the samples representing early stages of processing have very low grain to chaff ratios. In contrast, fine sieve by-products display significantly higher ratios which are, at the lower end of the range, similar to the grain:rachis ratio for unprocessed six-row barley and free-threshing wheat (3:1). The ratios in cleaned Amorgos products vary from *c*. 8 to 11565 and partly overlap with the fine sieve by-product ratios, showing that rachis internodes persist throughout processing and, in low numbers, occur also in the final product (Jones 1990).

AMORGOS BARLEY							
Winnowing by-product		**Coarse-sieve by-product**		**Fine-sieve by-product**		**Cleaned product**	
grain+ rachis	grain:chaff	grain+ rachis	grain:chaff	grain+ rachis	grain:rachis	grain+ rachis	grain:rachis
314	0.52	7175	1.35	221	220.00	52304	13075.00
380	0.48	1480	1.24	115	115.00	19702	9850.00
550	0.38	284	0.97	111	111.00	30707	4385.71
1065	0.30	612	0.76	110	110.00	8372	4185.00
576	0.25	3850	0.57	72	72.00	4111	4110.00
1202	0.23	280	0.56	59	59.00	15664	3915.00
268	0.20	936	0.42	58	58.00	15504	3875.00
392	0.18	1352	0.36	56	56.00	24037	3432.86
1335	0.15	3010	0.36	51	51.00	58818	3266.67
322	0.14	48128	0.36	49	49.00	46515	3100.00
948	0.13	1192	0.34	43	43.00	15205	3040.00
17726	0.12	1160	0.29	80	39.00	39383	3028.46
560	0.12	1692	0.28	67	32.50	2481	2480.00
38	0.12	3496	0.25	66	32.00	49942	1559.69
78	0.11	10200	0.20	55	26.50	78180	1302.00
518	0.09	556	0.20	31	14.50	23720	1185.00
1936	0.08	2830	0.18			12101	1099.09
392	0.06	311	0.11			26997	998.89
1658	0.06	3800	0.10			21730	723.33
1270	0.05	3112	0.07			35700	713.00
440	0.05	800	0.00			3886	646.67
2132	0.05					470	470.00
208	0.04					4350	434.00
130	0.03					25488	373.82
786	0.01					18655	338.18
228	0.00					6553	283.91
						1252	55.91

Table 5.3a Grain to rachis ratios of Amorgos barley calculated for the samples with minimum 30 barley remains (after Jones 1990)

The Amorgos ratios were compared to the Çatalhöyük data in two ways. First, the ratios for barley and free-threshing wheat were considered separately in relation to the relevant Amorgos data. Secondly, since the two crop types are processed in the same way and the crop material isolated in different processing stages would have similar composition in terms of plant parts (Jones 1984), barley and free-threshing wheat were combined and treated together as (potentially) deriving from a mixed or 'maslin' crop (cf. Jones 1984, 1990; Charles and Bogaard 2001; Bogaard 2004a; Hald 2008).

AMORGOS FREE-THRESHING WHEAT							
Winnowing by-product		**Coarse-sieve by-product**		**Fine-sieve by-product**		**Cleaned product**	
grain+ rachis	grain:chaff	grain+ rachis	grain:chaff	grain+ rachis	grain:rachis	grain+ rachis	grain:rachis
202	0.33	24100	0.69	271	270.00	100000	9999.00
192	0.23	936	0.64	180	179.00	9071	9070.00
528	0.19	1000	0.60	104	103.00	65148	8142.50
382	0.19	482	0.55	100	99.00	6801	6800.00
136	0.17	22770	0.55	97	96.00	15443	5146.67
346	0.13	1752	0.48	83	82.00	4250	4250.00
868	0.10	2504	0.47	172	56.33	63518	3527.78
504	0.09	1682	0.32	55	54.00	9960	2489.00
1374	0.09	1850	0.31	259	42.17	1400	1400.00
540	0.08	4832	0.29	37	36.00	70515	1083.85
111	0.08	1368	0.28	36	35.00	25754	1072.08
120	0.07	2888	0.24	35	34.00	32232	1006.25
608	0.07	1516	0.23	35	34.00	65668	964.71
1804	0.07	5435	0.19	33	32.00	11593	890.77
202	0.05	4796	0.15	30	29.00	22910	571.75
954	0.04	939	0.09	131	25.20	18174	533.53
820	0.04	1414	0.08	102	24.50	14888	530.71
1874	0.04	8200	0.02	89	11.71	10443	453.04
432	0.03	2390	0.01	165	10.00	19346	419.57
318	0.03			**107**	**8.73**	10445	416.80
760	0.02			32	2.20	17460	193.00
1944	0.01			31	0.94	774	192.50
514	0.01					9365	143.08
928	0.00					1555	61.20
1220	0.00					2185	32.62
						317	9.93
						74	8.25

Table 5.3b Grain to rachis ratios of Amorgos free-threshing wheat calculated for the samples with minimum 30 free-threshing wheat remains (after Jones 1990)

SUMMARY	**Amorgos free-threshing wheat**		**Amorgos barley**		**Wheat and barley combined**	
grain:rachis ratio	min.	max.	min.	max.	average min.	average max.
winnowing by-product	0.00	0.33	0.00	0.52	0.00	0.43
coarse-sieve by-product	0.01	0.69	0.00	1.35	0.01	1.02
fine-sieve by-product	0.94	270.00	14.50	220.00	7.72	252.25
cleaned product	8.25	9999.00	55.91	13075.00	32.08	11564.95

Table 5.3c Summary of grain to chaff ratios of the Amorgos free-threshing cereals

Barley grain:rachis ratios for the 14 Çatalhöyük samples containing at least 30 barley items (and hence yielding reasonably reliable figures) are presented in Table 5.4a. In most of these samples (11), barley grain:rachis ratio is 3.0 or more, exceeding the value expected for unprocessed six-row barley; in seven of these the ratio is significantly higher (>10). The remaining three samples contain lower ratios of grain to chaff (*c.* 1-3). Given that the inclusion of two-row barley in the samples should, if anything, decrease the Çatalhöyük ratios below those from Amorgos, the implication is that most of the barley material could derive from the fine sieve by-product stage, though varying degrees of admixture between product and by-product material cannot be excluded. The Çatalhöyük sample with the highest ratio (239, in Fl. 516) could resemble cleaned product.

ÇATALHÖYÜK BARLEY					
	Sample number	**Barley grain**	**Barley rachis**	**Total items**	**GRAIN:RACHIS**
1	516	239	1	240	**239.00**
2	535	155	3	158	**51.67**
3	23	93	2	95	**46.50**
4	11	238	9	247	**26.44**
5	45	127	8	135	**15.88**
6	1804	29	2	31	**14.50**
7	31-27.33.37	42	4	46	**10.50**
8	104	35	6	41	**5.83**
9	465	58	10	68	**5.80**
10	150	28	6	34	**4.67**
11	171.329	50	13	63	**3.85**
12	395	39	15	54	**2.60**
13	3399	40	20	60	**2.00**
14	16-31.49.64.1732	32	24	56	**1.33**

Table 5.4a Barley grain:rachis ratios for Çatalhöyük samples containing minimum 30 barley remains

Table 5.4b lists free-threshing wheat grain:rachis values for the 16 Çatalhöyük samples containing at least 30 free-threshing wheat items (and providing reasonably reliable ratios). Seven samples have grain:rachis internodes ratios of 3:1 or higher, and a few of them are remarkably rich in grain; in comparison with the Amorgos data, these samples are consistent with the fine sieve by-product stage. Only a few (4) are as grain-rich as the Amorgos cleaned products with low grain:chaff ratio, though the thoroughness of sieving can vary, and the most grain-rich sample (Fl. 135) could therefore represent (semi-cleaned) product. A further sample has a ratio (1.33) overlapping with the ranges for fine sieve by-products, while the remaining

nine samples are dominated by rachis and so resemble either winnowing or coarse sieve by-products. It is notable that free-threshing wheat is represented in the samples by apparently early stage by-product material, whereas the equivalent early stage by-products seem to be lacking for barley. This may imply that the two cereals have been grown and processed differently and separately.

ÇATALHÖYÜK FREE-THRESHING WHEAT					
	Sample number	**Free-treshing wheat grain**	**Free-threshing wheat rachis**	**Total items**	**GRAIN:RACHIS**
1	135	37	0	37	**37.00**
2	171.329	92	3	95	**30.67**
3	74.103	30	2	32	**15.00**
4	23	54	6	60	**9.00**
5	516	33	5	38	**6.60**
6	45	35	7	42	**5.00**
7	3297	20	15	35	**1.33**
8	677	14	101	115	**0.14**
9	16-31.49.64.1732	6	49	55	**0.12**
10	3399	4	74	78	**0.05**
11	1297.164	2	49	51	**0.04**
12	31-48.49.51	0	106	106	**0.00**
13	1950	0	55	55	**0.00**
14	5030	0	54	54	**0.00**
15	904	0	37	37	**0.00**
16	639	0	34	34	**0.00**

Table 5.4b Free-threshing wheat grain:rachis ratios for Çatalhöyük samples containing minimum 30 free-threshing wheat remains

The combined grain:rachis ratios for the two free-threshing crop types found in Çatalhöyük samples are shown in Table 5.4c, again focussing on the samples that contain at least 30 relevant items (here, barley *and/or* free-threshing wheat grain and rachis). Using the ratio values for free-threshing cereals observed in the Amorgos data, a general classification of the Çatalhöyük samples was carried out. Since only one of the selected samples reaches the lowest average ratio value of Amorgos cleaned products (32; Table 5.3c), it could be argued that they all represent by-products of various stages of cleaning – winnowing/coarse sieving or fine sieving. The separate comparisons of barley and free-threshing wheat with the Amorgos data discussed above suggest, however, that the two crop types were probably, at least in some cases, grown and processed separately since the early stage by-product 'signature' relates particularly to free-threshing wheat. The inference of separate processing is consistent with the evidence of separate storage (and perhaps also consumption) of these two

crops, as documented by *in situ* burnt stores discovered in recent excavations - for instance separate concentrations of naked barley and free-threshing wheat in Building 52, a naked barley store in Building 63, and a deposit of barley grain and peas (mixed with small fish bones - perhaps indicating food preparation) in Building 77 (Bogaard *et al*. 2008, 2009; Twiss *et al*. 2008).

ÇATALHÖYÜK FREE-THRESHING CEREALS					
	Sample number	**Free-threshing cereal grain**	**Free-threshing cereal rachis**	**Total items**	**GRAIN:RACHIS**
1	516	272	6	278	***45.33***
2	11	238	9	247	**26.44**
3	135	49	2	51	**24.50**
4	23	147	8	155	**18.38**
5	74.103	45	4	49	**11.25**
6	45	162	15	177	**10.80**
7	171.329	142	16	158	**8.88**
8	1804	29	4	33	**7.25**
9	535	158	27	185	**5.85**
10	104	35	8	43	**4.38**
11	465	58	16	74	**3.63**
12	31-27.33.37	54	21	75	**2.57**
13	150	28	17	45	**1.65**
14	3297	20	15	35	**1.33**
15	395	39	32	71	**1.22**
16	4545.4626	15	16	31	**0.94**
17	173	15	20	35	**0.75**
18	31-04.06.07	19	29	48	**0.66**
19	520	19	34	53	**0.56**
20	16-31.49.64.1732	38	73	111	**0.52**
21	3399	44	94	138	**0.47**
22	1297.164	22	57	79	**0.39**
23	27-13.15	8	24	32	**0.33**
24	588	9	35	44	**0.26**
25	674	7	28	35	**0.25**
26	677	23	108	131	**0.21**
27	904	7	38	45	**0.18**
28	1791	5	31	36	**0.16**
29	31-48.49.51	16	113	129	**0.14**
30	639	5	42	47	**0.12**
31	4361	3	34	37	**0.09**
32	1950	3	76	79	**0.04**
33	5030	0	57	57	**0.00**

Table 5.4c Free-threshing cereal (barley+free-threshing wheat) grain:rachis ratios for Çatalhöyük samples containing minimum 30 free-threshing cereal remains

5.3.2 **Crop processing analysis using the weed-based method**

Of particular interest for this project is the impact of crop processing on the weed composition of the samples. In order to assess the crop processing stage(s) represented by Çatalhöyük samples independently of their crop content, a method devised by Jones (1984, 1987) was followed that uses discriminant analysis to compare archaeological samples and ethnographic (Amorgos) samples (for which the processing stages are known) based on their wild/weed component (Section 5.2.1.2). For the purpose of the analysis, the physical types of all wild/weed identifications included in the crop-based analysis were determined, according to the physical characteristics used for classification of the Amorgos wild taxa: seed size, tendency of seeds to stay in heads (after threshing), and seed velocity (Table 5.5). Some of the wild taxa identified in the assemblage under study had already been classified by G. Jones as part of her work on the modern material from Amorgos and archaeological material from Assiros Toumba (1984, 1987); additional information about the seed properties were obtained from other relevant published work (Charles and Bogaard 2001, 2010; Bogaard 2004a; Valamoti 2004; Hald 2008). Wherever possible, data about physical properties of the actual Çatalhöyük taxa, or those that appeared closest to the present species/genus in terms of seed morphology/plant characteristics were used. Where the necessary information was not already available, observation of modern reference material (e.g. its size) and experimental work were conducted (see below). In cases of genus or type-level identifications, archaeological specimens were compared to the available modern material in order to generate common characteristics (size, 'headedness' and velocity) of species included in the identification.

The size of seeds was measured using a binocular microscope with an ocular graticule. By comparing the Çatalhöyük seeds to seeds of known physical type, and following Jones's size-based classification of Assiros weed seeds (1981), those of ≥1.5 mm in breadth were considered 'big', and those of <1.5 mm in breadth were described as 'small'. In consultation with Dr G. Jones, 'headedness' (i.e. tendency of seeds to stay in fruit despite threshing) of certain taxa was explored by way of rubbing seed heads/pods between hands. The determined seed size and headedness categories, as well as ambiguous taxa (e.g. *Stipa*, see below) were then tested against cereal grain by coarse-sieving through a 4 mm sieve a combination of modern hulled wheat (emmer) spikelets and selected small, big, free and headed weed seeds.

	TAXA	PHYSICAL PROPERTY CLASS	
1	*Centaurea* sp.	BFH	big-free-heavy
2	*Convolvulus arvensis* L. type	BFH	big-free-heavy
3	*Boreava orientalis* Jaub. & Spach	BFH	big-free-heavy
4	*Taeniatherum caput-medusae* L.	BFH	big-free-heavy
5	*Hordeum spontaneum* C. Koch type	BFH	big-free-heavy
6	cf. *Lallemantia peltata* L.	BFH	big-free-heavy
7	*Vicia* L./*Lathyrus* L.	BFH	big-free-heavy
8	*Fumaria* L.	BFH	big-free-heavy
9	*Polygonum convolvulus* L.	BFH	big-free-heavy
10	*Adonis annua/aestivalis* L.	BFH	big-free-heavy
11	*Galium aparine* L. type	BFH	big-free-heavy
12	*Beta* L.	BHH	big-headed-heavy
13	cf. *Secale* sp.	BHH	big-headed-heavy
14	*Stipa* L.	BHH	big-headed-heavy
15	*Lavatera* L. type	BHH	big-headed-heavy
16	*Polygonatum* Miller	BHH	big-headed-heavy
17	*Heliotropium* L.	SFH	small-free-heavy
18	*Vaccaria pyramidata* Medik.	SFH	small-free-heavy
19	*Atriplex* L.	SFH	small-free-heavy
20	*Chenopodium* L.	SFH	small-free-heavy
21	*Chenopodium album* L. type	SFH	small-free-heavy
22	*Salsola* L.	SFH	small-free-heavy
23	*Chenopodium chenopodioides* L. type	SFH	small-free-heavy
24	*Suaeda* L.	SFH	small-free-heavy
25	*Descurainia sophia* (L.) Webb	SFH	small-free-heavy
26	*Conringia orientalis* L.	SFH	small-free-heavy
27	*Capsella* Medik.	SFH	small-free-heavy
28	*Bolboschoenus glaucus* (Lam.) S.G. Smith	SFH	small-free-heavy
29	*Carex* L.	SFH	small-free-heavy
30	*Euphorbia* L.	SFH	small-free-heavy
31	*Erodium* L'Hérit.	SFH	small-free-heavy
32	*Geranium* L., small type	SFH	small-free-heavy
33	*Cornucopiae cucullatum* L. type	SFH	small-free-heavy
34	*Bromus danthoniae* Trin. type	SFH	small-free-heavy
35	*Eremopyrum* (Ledeb.) Jaub. & Spach	SFH	small-free-heavy
36	*Sideritis* L. type	SFH	small-free-heavy
37	*Ziziphora capitata* L./*persica* Bunge	SFH	small-free-heavy
38	*Teucrium* L.	SFH	small-free-heavy
39	*Leguminosae*, small wild	SFH	small-free-heavy
40	*Linum* L.	SFH	small-free-heavy
41	*Polygonum aviculare* aggregate	SFH	small-free-heavy
42	*Rumex* L.	SFH	small-free-heavy
43	*Androsace* L.	SFH	small-free-heavy
44	*Anagallis* L.	SFH	small-free-heavy
45	*Ranunculus* L.	SFH	small-free-heavy
46	cf. *Potentilla* L. type	SFH	small-free-heavy
47	*Galium verum* L. type	SFH	small-free-heavy
48	*Thymelea passerina* (L.) Cosson & Germ. type	SFH	small-free-heavy
49	*Valerianella* Miller	SFH	small-free-heavy
50	*Verbena officinalis* L.	SFH	small-free-heavy
51	*Viola* L.	SFH	small-free-heavy
52	*Potamogeton* L.	SFH	small-free-heavy
53	*Campanula* L.	SFL	small-free-light
54	*Helianthemum* Adans.	SFL	small-free-light
55	*Artemisia annua* L. type	SFL	small-free-light
56	*Aeluropus* Trin.	SFL	small-free-light
57	*Sporobolus* R. Br.	SFL	small-free-light
58	*Eragrostis* N. M. Wolf	SFL	small-free-light
59	*Crypsis aculeata* (L.) Aiton type	SFL	small-free-light
60	*Juncus* L.	SFL	small-free-light
61	*Alisma* L.	SFL	small-free-light
62	*Silene* sp.	SHH	small-headed-heavy
63	*Malva* L.	SHH	small-headed-heavy
64	*Hordeum murinum* L. type	SHL	small-headed-light
65	*Papaver* L.	SHL	small-headed-light

Table 5.5 Classification of wild/weed taxa into crop processing physical types

As regards seed 'lightness', Bogaard (2004a) conducted an experiment using a seed buoyancy machine and demonstrated that species classified as 'light' by G. Jones (1984) have low average velocities (<3.50 m/s), while 'heavy' species are those with high average velocities (>3.00 m/s), showing a small overlap zone. In order to apply this approach to the archaeobotanical taxa in the present study, seed velocity was explored using the same machine (Askew *et al*. 1997) installed at the University of Sheffield (Appendix 2). The <3.00 m/s arbitrary threshold was used for identifying 'light' species, while species with velocity greater than 3.50 m/s were classified as 'heavy'; the species with intermediate velocities (between 3.00 and 3.50 m/s) were classified as 'light' or 'heavy' depending on their morphological similarity to species falling within the definite 'light' and 'heavy' categories. The velocity of seeds depends on their weight, but also other properties such as presence of *pappus* (hairy attachment) or 'wings' etc, which enable some seeds to 'float' and be winnowed off in crop processing. With the use of the machine for measuring seed dispersal/velocity, these differences can be assessed objectively and plant species classified as 'light' or 'heavy'.

It should again be highlighted that the ethnographic samples from Amorgos consisted of free-threshing cereals, whereas hulled wheats form the chief crop component of the Çatalhöyük samples, with only a few samples dominated by pulse or representing a mixture of hulled wheat, free-threshing cereals and pulses (Section 4.3). The cleaning processes of hulled wheat and free-threshing cereals differ in terms of the number of stages and the range of plant elements found in the products and by-products of each stage (Hillman 1984b, 1985). There are, however, no ethnographic models of hulled wheat processing comparable to the one extracted from the Amorgos study. Nonetheless, because weed seeds are less likely to be affected by the differences between cleaning sequences for the two crop groups than are the chaff and straw components (Jones 1984), the separation of processing stages based on the identical weed seed characteristics can be applied. For example, it is plausible that the weed component of hulled wheat winnowing by-products would also consist of small-free-light seeds, because the universal purpose of this activity is to remove light material (light chaff and straw) from the harvested crop. Furthermore, in cleaning of hulled wheats, by-products of coarse sieving completed prior to dehusking would contain weed seed 'heads' larger than *spikelets* ('headedness' undermines the effect of weed *seed* properties - G. Jones pers. comm.) and other material such as pieces of straw and any unthreshed ears (Hillman 1984b). After pounding (which is intended to break 'heads'/spikelets to release seed/grain), any remaining

'headed' weeds would be represented as individual seeds, mixed with grain and glume bases (Hald 2008). In further (post-pounding) processing of hulled wheat, small-free-heavy seeds (and dense chaff fragments) would pass through the fine sieve, while grain-sized weed seeds (big-free-heavy) would be retained as the product requiring further hand-cleaning.

Drawing upon these observations, weed 'headedness' is seen as relevant in cases where weed seeds remain in the 'head' after threshing and the 'head' is at the same time larger than hulled wheat spikelets, since then it would presumably be removed in an early stage of processing (i.e. coarse sieving). Otherwise, if a 'head' survives threshing, but is spikelet-sized or smaller, it would accompany the crop for longer in the cleaning process (i.e. it would be bulk-stored with semi-cleaned grain and then broken up in pounding, releasing seeds - Hillman 1984b). Therefore, in determination of weed physical types, weed heads were examined in terms of their robustness/hardiness and their size compared to the average size of hulled wheat spikelet. This proved to be particularly useful for classification of some broadly identified taxa, for example small wild indeterminate legumes (encompassing several genera) which grow seeds in pods and could therefore be classified as 'headed' (and potentially removed in coarse sieving). However, after examination of modern specimens, it was determined that the potentially 'headed' taxa included in the identification can actually be classified as small-free-heavy, because the 'heads' (pods) are dehiscent (i.e. would be threshed and seed released); the seeds would likely be removed in fine sieving, together with other small-free-heavy taxa. Contrary to this, a large-seeded grass *Stipa*, with a spikelet of a similar size compared to hulled wheat spikelet, was classified as 'headed' as it was experimentally shown that it would be retained by coarse sieve due to the presence of a long awn (*callus*) that tends to remain attached even at maturity (Nesbitt 2006).

The final classification of wild/weed taxa into crop processing physical types is presented in Table 5.5. The Çatalhöyük samples were compared with the ethnographic data from Amorgos by performing a discriminant analysis in which modern samples of four main cereal-processing stages were used as 'control groups' for the archaeological dataset. For successful running of discriminant analysis, a minimum of ten [classifiable] weed seeds per sample is required (Jones 1987), and all of the selected samples met this criterion. Count values for each taxon across the samples were converted to percentages and square rooted to make the data more normally distributed (Jones 1984, 1987). They were then entered into SPSS (Norusis

2002) together with the relevant data for Amorgos samples; the results of the discriminant analysis are illustrated by plotting archaeological and modern samples along the discriminant

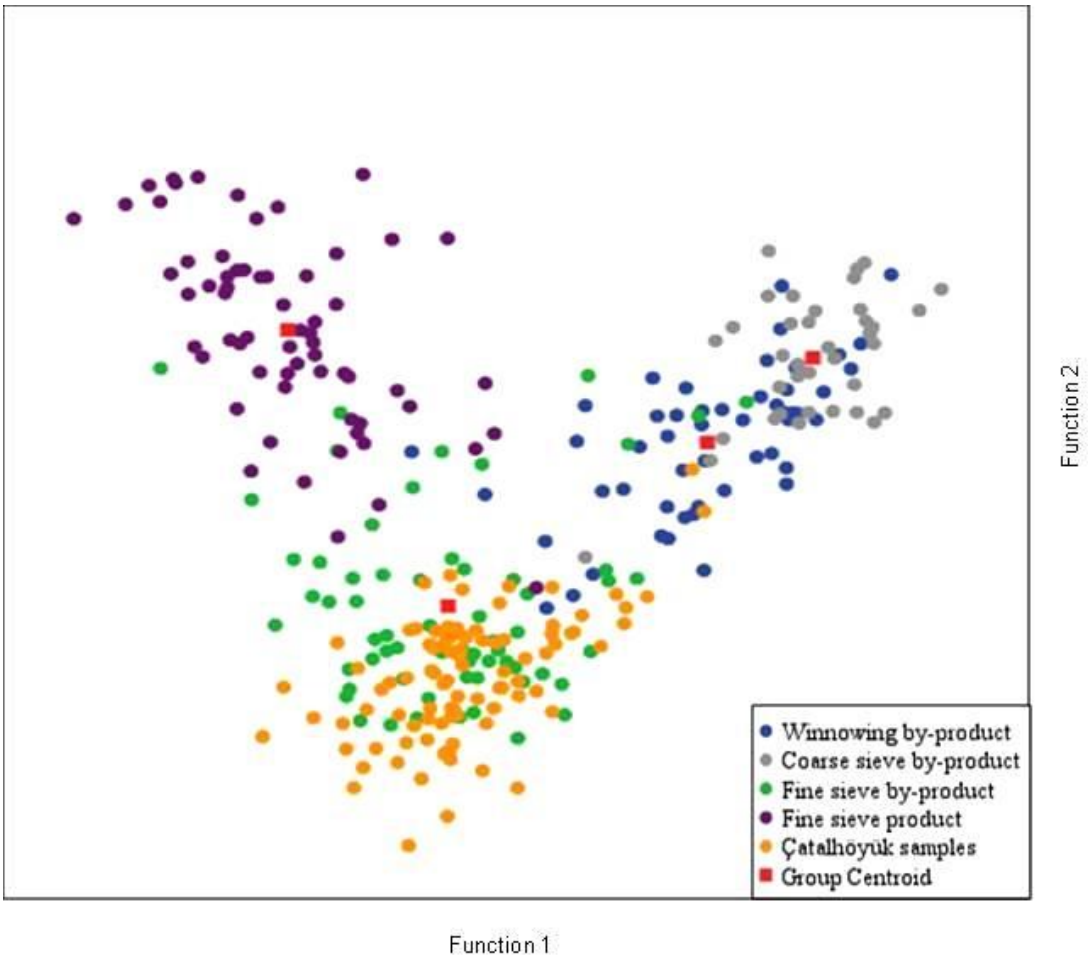


Figure 5.2 Scatter plot of the Çatalhöyük and Amorgos samples based on a discriminant analysis of the four crop processing groups

functions (axes 1 and 2), as shown in Figure 5.2. Based on similarity between the two groups of samples in the number of items within the six different weed seed groups, and similarity in the combination of the groups in the samples, archaeological samples were classified as either by-products of winnowing (28 samples) or by-products of fine sieving (66 samples). Table 5.6 shows the classification of samples by the discriminant functions, and the levels of classification probability; with a few exceptions, the probabilities are high, but it should be emphasised that they reflect the level of similarity of the archaeological samples to a particular processing group represented by the ethnographic samples - they are not an absolute indicator of the origin of individual samples (Charles and Bogaard 2001: 312-313). The categorisation of all 94 samples as winnowing or fine sieve by-products is in accordance with

the overall prevalence of weeds seeds with characteristics associated with the respective crop processing stages[1], as shown in Table 5.6). Small-free-heavy seeds, found in fine sieve by-product samples from Amorgos, are the most abundant and frequent in majority of the Çatalhöyük samples, followed by small-free-light taxa, characteristic of Amorgos winnowing by-product samples. Despite the occurrence of a few headed taxa in the assemblage, none of the samples were classified as coarse sieve by-products since, by comparison to the modern dataset, headed taxa were not present in significant numbers. It has been noted before that charred remains of early by-products are relatively rare in archaeological deposits as the early stages of processing tend to take place outdoors and 'off-site' (e.g. on threshing floors - Hillman 1984a, b; Jones 1984; Fuller and Weber 2005; Fuller and Stevens 2009).

5.3.3 **Synthesis of the results from crop processing analysis**

The overall picture from the weed-based crop processing analysis is more or less in agreement with inferences made from the crop-based analysis (see Table 5.7 for the combined results and Table 5.8 for the summary). The crop- and weed-based classifications of the 74 *hulled wheat samples* (excluding the ten *Descurainia*-samples; Section 5.3.1.1) produced compatible results, indicating that the samples could represent unmixed processing stages: they potentially originate from residue of winnowing and/or fine sieving of pounded hulled wheats (in the case of 71 glume base-dominated samples), or from (stored) crop in the form of semi-cleaned grain accompanied by weed seeds (represented by the three 'spikelet' samples). In other words, it would appear that both 'winnowable' and 'fine-sievable' weed species accompanied semi-processed (stored) spikelets, and that both winnowing and fine sieving were applied in cleaning of hulled wheats after dehusking (Section 5.2.1). On the assumption, however, that most 'winnowable' (free-light) material would be removed in initial/off-site winnowing of spikelets (prior to storage/dehusking - Hillman 1984b; Jones 1984), and that subsequent winnowing of pounded/dehusked spikelets would produce a by-product made up mostly of chaff and not much weed material (Bogaard 2004a), the classification of the 28

[1] As an illustration, the ten *Descurainia*-samples, which were considered 'anomalous' in the crop-based crop processing analysis (where they were included based on the dominance of hulled wheat in their crop content - Section 5.3.1.1), as well as another five previously recognised *Descurainia*-rich samples (Section 4.4, Fig. 4.14a-b) were all classified as fine-sieve by-products because of the characterisation of *Descurainia* seeds as small-free-heavy. In order to explore the possible 'effect' of *Descurainia* in 'non-*Descurainia* samples', the analysis was repeated without it (plot not shown); the exclusion of *Descurainia* resulted in more samples classified as winnowing by-products (37) and fewer samples classified as fine sieving by-products (56), while a single sample with <10 weed seeds was eliminated.

samples (of which 26 are hulled wheat samples) as winnowing by-products is questionable. This raises a possibility that the winnowing by-product samples are not 'real' and that sources of wild seeds alternative/additional to crop processing (e.g. animal dung) may have contributed to their composition. Further assessment of the potential non-arable/dung origin of some wild/weed taxa is discussed in the sections that follow.

Crop processing classification	**Hulled wheat samples**		Pulse samples		Mixed crop samples	
	Glume base	Spikelet	(Unprocessed) lentil sample	Pulse seed sample	Glume base	Spikelet
Winnowing by-product	24*	2*		1		1
Fine sieve by-product	47*	1*	1*		1	1
Descurainia samples	5	5			3	2

***** - sample types with 'compatible' crop- and weed-based classifications consistent with potentially unmixed processing stages

Table 5.8 Summary of results of the crop processing analysis

Of the three 'mixed crop' samples (after exclusion of the remaining five *Descurainia*-dominated samples, see Table 5.7), two were classified as a fine-sieve by-product/spikelet sample and a fine-sieve by-product/glume bases sample; the hulled wheat component of the former could therefore represent semi-cleaned grain, and of the latter - residue from fine sieving. The lentil sample (Fl. 144) was classified as by-product of fine sieving based on its wild/weed content, which is in agreement with its 'unprocessed' status suggested earlier (Section 4.3.2). The other pulse sample was classified as by-product of winnowing due to the large number of small-free-light taxa in it, which, as noted, may in fact derive from dung fuel burning (see below).

5.4 Dung-derived plant material at Çatalhöyük

The four main analytical criteria for identifying dung-derived charred plant material in archaeobotanical samples set out by Charles (1998) were applied to the Çatalhöyük dataset in an attempt to assess the likelihood that any of the identified remains originate from burnt animal dung. Additionally, observations from the relevant experimental work (e.g. Gardener *et al*. 1993; Valamoti and Charles 2005; Wallace 2007; Wallace and Charles in press) were

drawn upon as an aid in understanding of the role of dung-derived material in the archaeobotanical assemblage (see above, Section 5.2.3)

5.4.1 **Presence of recognizable animal dung in archaeological deposits**

In previous work at Çatalhöyük, charred dung remains were widely observed in building fills and external deposits; it has therefore been suggested that dung was commonly burnt as fuel (Fairbairn *et al*. 2005a). Furthermore, deposits containing complete mineralised dung pellets were observed in the earliest levels of the settlement (Pre-Level XII/South G) in Space 181 in the South Area, suggesting large-scale use of dung as fuel, here perhaps in association with preparation of lime for use as wall and floor plaster (Fairbairn *et al*. 2005a; Cessford 2007a). Concentrations of mineralized seeds from penning layers in external Space 199 were also considered to have derived from dung (Fairbairn *et al*. 2005a).

Micromorphological examination of sediment thin-sections showed that dung-burning deposits in Space 181 included calcareous spherulites - crystals encountered in ancient and modern dung samples which form in the gut of grazing animals during digestion (Matthews 1999, 2005a). The apparent penning deposits in Space 199 were identified based on laminated layers of compressed herbivore dung rich in siliceous micro-remains of plants (particularly reed cells, grass awns and epidermis and siliceous pericarps of seeds); flecks of charred plant remains were also present (Matthews 1999, 2005a). These finely bedded deposits were similar in their colour, texture and chemical content to ethnoarchaeological samples of herbivore stable deposits (Matthews *et al*. 1996). The micromorphological investigation of the earlier Neolithic sequence at Çatalhöyük also revealed the presence of herbivore dung in a wide range of contexts, from fire installations and rake-out deposits within buildings, to lime-burning areas and deposits in open areas and middens (Matthews 1999, 2005a, 2010, 2012). Matthews (2005a) reports three types of dung identified in soil thin-sections: small oval pellet fragments probably from ovicaprids; large aggregates of partially digested plant materials (including reeds) probably from ungulates (cattle or equid) and aggregates from omnivore coprolites (pig, dog, and human), which sometimes contained bone fragments. Amorphous organic aggregates/omnivore dung was, for instance, discovered mixed with building material in fill above the floor of Space 117 in Building 2; some buildings contained loose aggregates of herbivore dung pellets, probably from sheep and goats (e.g. Building 8), while an area with

compacted herbivore dung, maybe stored for fuel, was discovered in Space 182 in Building 17 (Matthews 2005a).

In the present study, charred remains of dung were recognized in twenty-eight samples from various context types, within and external to buildings (Table 5.9). Complete dung pellets were found in ten samples and were identified as sheep/goat based on the characteristic shape and pointed end of the pellets, as well as their distinctive surface texture (cf. Charles 1998: Fig. 1; Akeret and Jacomet 1997: Fig. 2; Linseele *et al*. 2010: Fig. 4). Nineteen samples contained fragments of dung which were not immediately identifiable as sheep/goat, but on closer inspection of the outer surface (where preserved) and internal texture, and by comparison to the complete sheep/goat pellets, it was determined that the fragmentary dung also derives from sheep/goat. In nine samples, seeds of wild taxa (*Bolboschoenus glaucus*, *Sporobolus*, *Carex*, *Polygonum* cf. *aviculare* and *Chenopodium*), embedded in dung fragments or with dung adhering to them were encountered; four of these samples also contain whole of broken sheep/goat pellets. Though the complete pellets were not dissected, the co-occurrence in several samples of charred seeds embedded in dung fragments with complete or fragmented sheep/goat pellets argues for a sheep/goat dung origin of the seeds. Cereal remains were not observed in physical association with dung; this negative evidence is in agreement with the generally very poor survival of cereal grain and chaff in sheep/goat digestion as shown in the feeding experiments (Valamoti and Charles 2005; Wallace 2007; Wallace and Charles in press). Although cereals are conceived as (primarily) human staple food not fed to livestock, the lack of cereal remains associated with dung cannot be taken as the evidence against cereal foddering (which could have been practiced regularly or in cases of spoiled/moldy, insect-infested or surplus grain).

Plant material embedded in the matrix of dung pellets points directly to animal ingestion and survival through the digestive system (Charles 1998; Hastorf and Wright 1998). At Çatalhöyük, plant material physically associated with dung is represented by seeds embedded in dung or with dung fragments adhering to them, and they are of the seed type likely to survive digestion (Section 5.2.3): for example, hard-coated *Bolboschoenus* and *Polygonum*, small-sized *Sporobolus*, hard-coated *and* small-sized *Chenopodium* and *Carex*. It is plausible that these taxa represent aspects of animal diet rather than post-digestion mixing in the manufacture of dung cakes (Anderson and Ertuğ-Yaraş 1998) or in fire installations as fuel sources (Bottema 1984). It cannot, however, be assumed that the taxa observed in physical

association with dung invariably derive from burning of dung fuel; in other contexts/samples they could have arrived by other routes (e.g. via crop processing). Therefore, the relevance of dung for the rest of the assemblage must be explored on alternative grounds; hence other criteria proposed by Charles (1998) were applied to the dataset, in order to assess the possibility of dung-derivation for some/all of the plant material.

5.4.2 **The biology and ecology of non-crop (wild/weed) taxa**

Consideration of the biology and ecology of the identified wild taxa was aimed at determining their likelihood to grow in arable fields, based on the preferred habitat type, and/or to be harvested in fruit (i.e. bearing seeds) together with crops, based on the similarity of their flowering/fruiting times with those of the associated crops. Palatability (acceptability of feed) and accessibility to animals (e.g. possession of various defence mechanisms protecting the plant from grazing) was also considered for the taxa unlikely to be found in arable fields and/or not harvestable in fruit, since they probably entered the archaeobotanical record by other route(s) such as animal dung burnt as fuel.

5.4.2.1 **Habitat types**

Table 5.10 lists the 68 wild/weed taxa (including taxa represented by mineralised remains) identified to genus or species level (Section 4.4) for which relevant information on the habitat preferences were available. The majority of taxa (40) are (primarily) dryland and can grow in cultivated fields or other disturbed habitats (e.g. ruderal taxa growing on field boundaries and invading fields); indeed, some of them appear to be confined to arable/ruderal areas (e.g. *Boreava orientalis* Jaub. & Spach, *Conringia orientalis* L., *Chenopodium album* L. type, *Fumaria* L., *Capsella*, small-seeded legumes). Another group of taxa (6) is normally found in non-arable dryland situations, such as hill slopes, rocky outcrops, forests (e.g. *Polygonatum* Miller), or steppe/grassland and meadows (e.g. *Stipa*, *Taeniatherum*) - all potential animal-grazing areas. However, it is not unusual for plants to 'escape' from one to another ecologically similar/favourable habitat (Holzner 1978; Grime *et al*. 1988, 1990); hence the taxa in question cannot be excluded as potential weeds. Of the dryland taxa, two were observed in physical association with dung - *Chenopodium* and *Polygonum*; these taxa tend to occupy a late seasonal niche in the Mediterranean arable cycle and occur in abundance in the stubble of harvested cereals (Ellenberg 1988).

Twelve taxa prefer damp and/or saline environments, in general not suited for cultivation of the recorded crop species (Davies and Hillman 1988). However, their role as arable weeds should not be excluded, since ethnographic observation suggests that even some wetland species can invade cultivated fields - for example, *Phragmites australis* and *Bolboschoenus* documented in poorly drained arable fields in Turkey (Davies and Hillman 1988; Hillman 1991); also, *Phragmites* has invaded present-day fields around Çatalhöyük (pers. observation), and *Bolboschoenus* occurs in summer-dry habitats (Hroudová *et al*. 2007). It is notable that some of the seeds observed in connection with dung (see above) belong to the taxa in this group (*Bolboschoenus, Sporobolus*), and that these occurrences relate to different ecological contexts compared to those that yielded potential 'stubble weeds' observed in dung (*Chenopodium, Polygonum*). This may imply that two separate/contrasted grazing habitat types (arable stubble *vs*. wetlands) are represented in the samples. Furthermore, seeds of all other species in the wetland/saline group possess similar physical and anatomic properties (small size, hard seed-coat) and are potentially well-equipped to survive animal (sheep/goat) ingestion (Russi *et al*. 1992; Hastorf and Wright 1998; Valamoti and Charles 2005).

Aquatic/open water taxa (*Alisma, Lemna, and Potamogeton)* are adapted to living in a very specific habitat type, clearly unsuitable for growing of the crops attested at the site; they can therefore be disregarded as possible weeds and would not have arrived at the site through crop processing; they could have potentially derived from animals drinking from water reservoirs.

5.4.2.2 **Flowering/fruiting time (seasonality)**

The fruiting time of specialized crop weeds tends to coincide with that of the crops with which they grow, while other potential weed taxa may pursue a more opportunistic strategy and have an extended period during which they produce seed (Grime 1979, 2002), or start setting seed after the harvest time (e.g. *Prosopis* - Charles 1998). Information about flowering (but not specifically fruiting) period for the majority of taxa documented at Çatalhöyük is available in *Flora of Turkey* (Davis *et al*. 1965-1988). Since the period from the onset of flowering to initial seed set is typically up to one month (J. Hodgson pers. comm.), the period from the second month of flowering onwards was used to estimate fruiting time.

The 68 Çatalhöyük wild/weed taxa grouped according to their (inferred) fruiting times in relation to the approximate harvest time are listed in Table 5.11. As noted by Fairbairn *et al*.

(2005a), in Anatolia today winter crops mature by June; in irrigated arable fields surrounding the mounds of Çatalhöyük harvest happens throughout July (pers. observation). The Çatalhöyük palaeoenvironmental model proposed by Roberts *et al*. (1999, 2001; Roberts and Rosen 2009) suggested a warmer climate *c*. 9000 years ago; thus it has been inferred that crops would have come to harvest slightly earlier than today (cf. Fairbairn *et al*. 2005a). For the classification of archaeobotanical taxa based on the flowering/fruiting period, a broad determination of June and July as likely crop harvest months in the past was, therefore, used.

'Early' taxa

In the 'early' group a few species flower and fruit before and during harvest time only, and some of them appear to be specifically adapted to the growth cycle of crops: they are annuals, occur in arable/ruderal (dry) environments and set seed at the time crops do. It is plausible that their seeds arrived on site with crops and have been incorporated in archaeological deposits as crop processing residues. In the case of *Descurainia sophia*, it should be emphasized that, while this taxon may well have grown as a weed in crop fields, *in situ* burnt stores of these seeds point to separate collection (Section 4.4).

'Intermediate' taxa

The majority of the Çatalhöyük wild/weed taxa have potential fruiting times that commence a few months before the harvest, overlap with that of the crops, and extend (well) beyond the harvest months, implying that they could have been harvested along with (winter) cereal crops, but other routes must be taken into account. As noted above, seeds of two taxa in this group (*Bolboschoenus* and *Sporobolus*) were found embedded in dung fragments and so are dung-derived in at least some instances. The 'ambiguity' of the taxa in this group as regards arable habitats is also supported by the fact that they have diverse ecological preferences, from cultivated fields to hills and grassland to wet places. Whereas the majority of the intermediate taxa occur in dry environments, several taxa, including the dung-related *Bolboschoenus* and *Sporobolus*, occupy wetland habitats (edges of rivers and lakes, salt marshes) which may have represented grazing areas during the dry season. The three aquatic species also fall into this group; they have been excluded as potential arable weeds based on their preferred habitat but could have been ingested by animals.

'Late' taxa

The taxa in this group set seed during but also after the suggested crop harvest time (from June to July); while it is possible that they arrived on-site with the crops and were preserved as discard from crop processing, they are more likely to have arrived via other routes, including animal diet. In fact, seeds of two late-fruiting taxa were found in association with dung (*Chenopodium* and *Polygonum* cf. *aviculare*, see above). The only taxon that comes into fruit exclusively *after* harvest time in the assemblage is *Phragmites australis* (reed). In the Çatalhöyük samples, reed is attested mainly by the presence of its culm nodes (which are the hardest parts of the stem and most likely to survive charring); some rhizome fragments could also belong to this taxon. If considered an arable weed, *Phragmites* would not have been harvested in seed with the crops due to its late fruiting time; the stems would have been removed with cereal straw in threshing and perhaps fed to animals or used for other purposes (as basketry and building material, fuel etc - Fairbairn *et al*. 2005a; Rosen 2005; Ryan 2011). The soil micromorphological analysis revealed abundant presence of cells of reed stems and leaves within dung-rich deposits, such as those in animal pens, and reed appears to be one of the most commonly occurring plant taxa in the micromorphologically analysed herbivore dung (Matthews 2005a).

5.4.2.3 **Palatability**

Plant palatability is the pleasing or satisfying aspect of feed or food (van Soest 1987: 9) and refers to characteristics such as flavour, smell, hairiness, and digestibility which render plants/plant parts acceptable for consumption by animals (Garner 1963). Palatability of plants depends on various factors (Garner 1963; van Soest 1987) of which seasonal variability is the one most relevant to this study, since the Çatalhöyük wild/weed flora under consideration is represented in its regenerative phase of growth, which takes place over a more or less determined period in an annual cycle (Elger and Barrat-Segretain 2004). Another element in assessment of whether some/all identified wild taxa could have been eaten by animals is plant 'accessibility', that is, presence of defence mechanisms protecting the plant from herbivores (Charles 1988).

The selection of forage by grazing animals directly depends upon amount and type of available herbage (Hussain and Durrani 2009). Most forage/feed sources for ruminants include grasses (grass and grass-like plants, including sedges), legumes (herbaceous legumes),

forbs (non-legume broad-leafed herbs) and browse (woody plants, shrubs and trees) (van Soest 1987: 12). Plant preferences of livestock shift with the seasonal growth cycle of plants, from shoots/whole plants, to foliage/leaves to floral parts as they become available, with the overall preference for flowers and fruits (Hussain and Durrani 2009). It has been ethnographically observed that flowers and fruits are very important seasonal source in animal diet (Ertuğ-Yaraş 1997) and that sheep generally prefer grasses, while goats prefer shrubs (Hussain and Durrani 2009).

Using available botanical information on palatability and morphology at the time of fruiting as well as ethnographic and personal field observations (e.g. Townsend and Guest 1947; Davis *et al*. 1965-1988; Ertuğ-Yaraş 1997; Fairbairn *et al*. 2005a), it was established that the majority of the identified wild taxa could have potentially been eaten by livestock and hence could have appeared at the site as a result of animal grazing/feeding. The possible exceptions to this, in terms of accessibility (e.g. plant defence mechanisms), are several spiny *Astragalus* species; the aquatic taxa, though floating or submerged, could have been taken in with drinking water. Another aspect that may be worth mentioning is the toxin content in plants, which may reduce palatability (van Soest 1987; Grime *et al*. 1990). In fact, all plants contain defensive compounds (including toxins), and herbivores cannot avoid their ingestion, but they can regulate the intake depending on the concentration and the kind of resistance substance in the plant; for instance, different toxins have different (sometimes adverse) effects on the body and animals are capable of limiting/avoiding the intake of any one plant (e.g. Lisonbee *et al*. 2009; Villalba and Provenza 2009). Among the identified wild/weed flora, a single taxon is probably unpalatable to livestock - the highly toxic *Anagallis arvensis* L. - while some other taxa are relatively unpalatable, such as *Galium verum* L. and *Chenopodium album*; the latter could be toxic if eaten in large quantities (Grime *et al*. 1990).

5.4.3 **Behaviour of non-crop taxa in relation to crop processing**

From the preceding discussion it is apparent that certain wild plant taxa in the Çatalhöyük assemblage are dung-derived in some cases. Several of the taxa observed embedded in dung are highly frequent in the assemblage (*Bolboschoenus glaucus, Sporobolus, Chenopodium*). It is therefore possible that dung-derived wild plant seeds occur in large numbers in the samples and that the effects of dung-fuel burning are pervasive across the assemblage.

The third criterion for recognition of dung-derived plant material addresses the issue indirectly at the 'assemblage level' by assessing whether the combination of wild taxa in the samples is consistent with the effects of crop processing, or whether instead the archaeobotanical samples in question form a coherent group in terms of wild/weed taxa, distinct from crop processing stages (Charles 1998). In the weed-based crop processing analysis (Section 5.3.2), the Çatalhöyük samples were compared to the ethnographic samples of known crop processing stage (Jones 1984, 1987) and they were classified, with a generally high probability, as winnowing or fine-sieve by-products (Table 5.6). This analysis was based on the assumption that the wild taxa classified in terms of their physical attributes relevant to crop processing (i.e. size, headedness, aerodynamic properties) represent weeds harvested with the (dominant) crop. Following Charles' approach (1998), all samples are now entered in the discriminant analysis as a separate ('fifth') group, additional to the four predefined ethnographic sample groups from Amorgos (Figure 5.3). Rather than with the Amorgos groups, the majority of samples (*c.* 98%; 92 out of 94) were re-classified into this separate group with a relatively high probability (Table 5.12). Furthermore, the overall

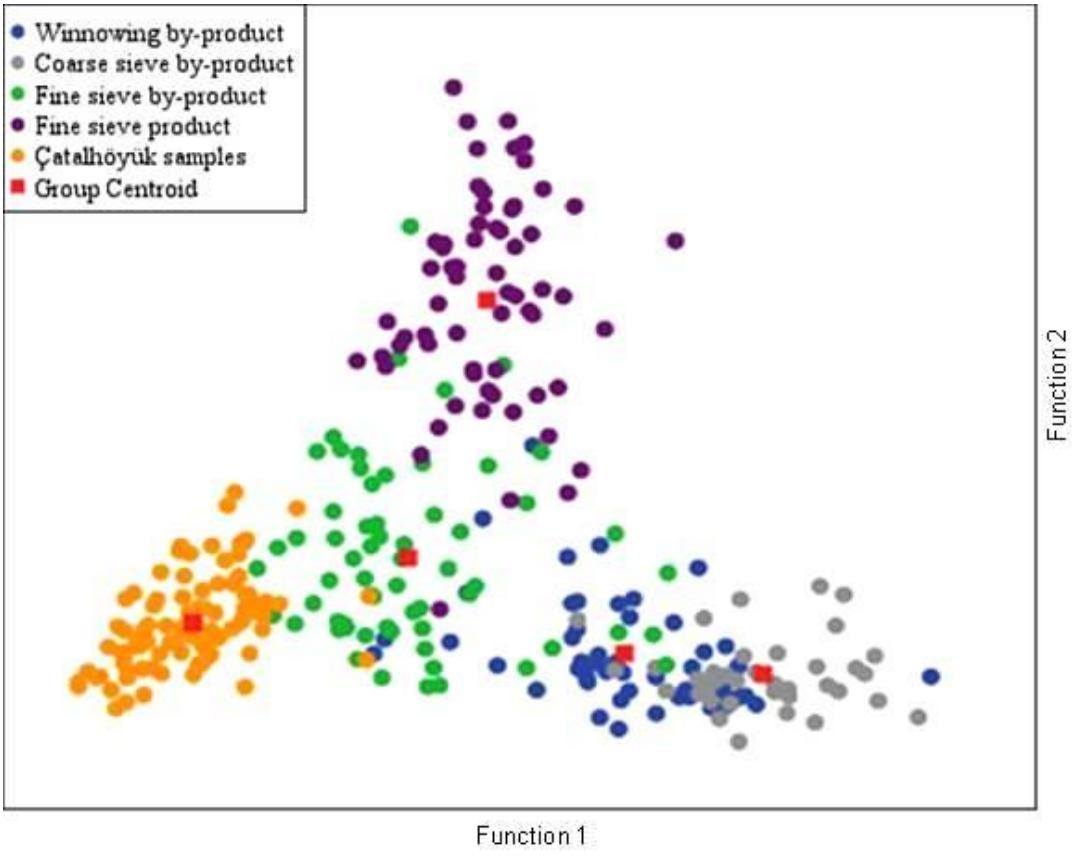


Figure 5.3 Scatter plot of the Çatalhöyük and Amorgos samples based on a discriminant analysis; Çatalhöyük samples entered as a separate group

configuration of the scatter plot of Amorgos samples along the first two discriminant functions was altered by inclusion of the Çatalhöyük samples as a separate group. By comparison, the assemblage from the third-millennium cal. BC site of Tell Brak in Syria, which more closely resembled the Amorgos groups and appeared relatively unaffected by dung, did not have this effect on the overall configuration of the discriminant analysis scatter plot (Charles 1998). The results suggest that the wild seed type composition of Çatalhöyük samples is different from that of the ethnographic groups, and that the source of at least some of the wild material may not be crop processing. The outcome of the analysis is similar to the situation observed at the third-millennium cal. BC site of Abu Salabikh in Iraq (Charles 1988), where the samples introduced as an alternative (fifth) group in discriminant analysis also formed a distinct cluster compared to the ethnographic samples.

5.4.4 **The relative proportions of crop types and plant parts (grain and chaff)**

This method takes into account the proportions of crop types and plant parts represented in archaeological samples and their relation to those 'expected' at particular stages of crop processing (Charles 1998). It is anticipated that only crops with similar cleaning requirements would be grown *and* processed together (e.g. Hillman 1981; Jones 1990); recurring combinations of 'incompatible' crop types and/or plant parts may imply deliberate mixing, possibly in the context of fodder or dung cake preparation.

The Çatalhöyük samples were classified into hulled wheat samples (84), pulse samples (2), and mixed crop samples (8) based on the relative predominance of crop types within the samples' crop content (Section 4.3.3). Overall, it is clear that mixing of incompatible crop types/plant parts was not widespread in the deposits and that they are instead, in crop terms, dominated by hulled wheat (more precisely, hulled wheat dehusking residues - Section 4.3.3). Investigation of the combination of crops and plant parts in the eight mixed crop samples shows that they do not derive from a single crop processing stage (Table 5.13). Instead, they appear to contain a mixture of processing stages of different crop types, for example semi-cleaned hulled wheat product (spikelets) combined with free-threshing cereal fine-sieve by-product (as determined by grain:chaff ratios; Fl. 11, Fl. 23, and Fl. 171.329) or hulled wheat winnowing/fine-sieve by-product (i.e. glume bases) mixed with barley product (Fl. 516). A combination of hulled wheat winnowing/ fine-sieve by-product and free-threshing cereal fine-sieve by-product (Fl. 45) does not imply that the material derives from the same processing

'event', since cereal chaff of the two crop groups is removed in a different way and at different stages in the processing sequence (Section 5.2.1).

Sample number	Crop group	Predicted group in discriminant analysis	Hulled wheat grain:chaff ratio group	Barley grain:chaff ratio group	Free-threshing wheat grain:chaff ratio group	*Descurainia* sample
516	mixed crop	Fine-sieve by-product	glume bases	Product	Fine-sieve by-product	X
87	mixed crop	Fine-sieve by-product	glume bases			X
45	mixed crop	Fine-sieve by-product	glume bases	Fine-sieve by-product	Fine-sieve by-product	X
4732	mixed crop	Fine-sieve by-product	glume bases			
23	mixed crop	Fine-sieve by-product	spikelet	Fine-sieve by-product	Fine-sieve by-product	X
3351	mixed crop	*Winnowing by-product*	spikelet			
11	mixed crop	Fine-sieve by-product	spikelet(/grain)	Fine-sieve by-product		X
171.329	mixed crop	Fine-sieve by-product	spikelet(/grain)	Fine-sieve by-product	Fine-sieve by-product	

Table 5.13 Crop processing classification of the eight mixed crop samples

It may be the case that some of the mixed-crop samples represent deliberate mixing (e.g. for fodder) but it is also evident that such mixing was not common across crop types (and on the assemblage-level). This situation contrasts with that at Abu Salabikh, where glume wheat chaff and (unprocessed) barley were combined systematically (Charles 1998). At Catalhoyuk, it is possible that residues of separately processed crops were occasionally combined in household refuse.

The effect of animal (sheep) digestion on crop material has been explored experimentally, and it has been demonstrated that the survival ability of crop material is very low, for both hulled and free-threshing cereals (Valamoti and Charles 2005; Wallace 2007; Wallace and Charles in press); ingested cereal grains are considerably damaged and hardly recognisable, while cereal chaff may survive and be identifiable as such, but in a significantly distorted form. Given the generally very good preservation of crop remains in the Çatalhöyük samples, it does not seem likely that they represent aspects of foddering; even where remains of different cereal types

are combined together, this could be a result of post-processing/post-depositional mixing. Chaff could have been mixed with dung in order to form dung cakes used as fuel (Miller and Smart 1984; Anderson and Ertuğ-Yaraş 1998; Hastorf and Wright 1998), or could have represented fuel on its own - used as tinder in dung-fuelled fires (Ertuğ-Yaraş 1997; Bottema 1984) and/or mixed with dung-derived material after 'primary' deposition, e.g. in cleaning of hearths/ovens when waste would have been deposited in middens (Martin and Russell 1996).

5.4.5 **Summary of the identification of dung-derived material**

Recognition of a suite of wild taxa as dung-derived in at least some of the Çatalhöyük samples offers a basis for inferences on seasonality of plant consumption (i.e. during the period of seed maturity of each taxon) and type(s) of habitat used for grazing and/or fodder collection. Table 5.14 summarises seasonality and broad habitat type (dryland versus wetland) information for the considered wild/weed taxa together with their physical characteristics in relation to crop processing, and their occurrence in physical association with dung. The taxa observed in dung are either of intermediate seasonality and occupying wetland habitats (*Bolboschoenus, Sporobolus*), or are late and found on dry land (*Chenopodium*, *Polygonum*); *Carex* thrives in both dry and wet conditions. It appears that resources in two distinctive environments - wet (non-arable) areas (salty marshes, freshwater places, river banks) and dry (arable/ruderal) land - were consumed by sheep(/goat), and potentially over an extended period - from early spring through to autumn.

From a crop processing perspective, the taxa related to dung are small-free-light (*Sporobolus*) or small-free-heavy (*Carex*, *Chenopodium*, *Bolboschoenus*, *Polygonum*); the former characterise winnowing by-products, the latter fine-sieve by-products. Bearing in mind the high frequency and abundance of these taxa in the samples (especially *Bolboschoenus* - Table 4.6b), the crop processing classification of samples based on the wild/weed physical types may in part reflect the influence of dung. The ambiguity also emerges when the Çatalhöyük samples are entered in the discriminant analysis as a separate pre-defined group - the majority of the samples are classified as distinct compared to the ethnographic classes. Of specific interest are small-free-light taxa, which include small-seeded grasses and other small-seeded taxa (i.e. *Helianthemum, Juncus, Artemisia*) producing minute-sized seeds (*c*. 0.3-1 mm) that can survive through the animal gut (e.g. Linseele *et al*. 2010). Some of these taxa have been observed in connection with dung at other sites (e.g. Charles and Bogaard 2005, 2010) and,

notably, in samples from the later Neolithic levels at Çatalhöyük (Bogaard *et al*. in press/2013; A. Bogaard, M. Ergun, pers. comm.). The suite of small-seeded grasses in the Çatalhöyük assemblage (*Aeluropus*, *Crypsis*, *Eragrostis*, *Sporobolus*) appear to be particularly adapted to herbivore grazing (see Section 7.2.2): in addition to the habitat preference (unproductive areas in terms of crop growing), their height is relatively small (10-30 cm) compared to other grasses and they have prostrate ('horizontal') growth habit, with seeds located close to leaves (as in *Aeluropus*) to ensure consumption by animals, which in turn promote seed dispersal (van Soest 1987; Charles and Bogaard 2010). Based on all this, the relevance to crop processing of taxa characterised as small-free-light seems problematic and the classification of the Çatalhöyük samples winnowing by-product could not be justified.

A multivariate approach - correspondence analysis - is applied (Ch. 6) in order to further investigate how different groups of wild/weed taxa behave in relation to each other and to crop remains, with the central aim of distinguishing between potential arable weeds and dung-derived plant material. Subsequently, dung-derived taxa are assessed in order to shed light on animal feeding practices, while the weeds are considered as evidence of crop growing conditions and husbandry practices (Ch. 7).

Chapter 6 Exploring variability across the assemblage

In this chapter, variation in the composition of the samples is explored using a multivariate ordination technique, correspondence analysis (Section 3.7.2); the aim is to identify associations of taxa deriving from different activities (e.g. wild taxa deriving from dung fuel burning versus crop processing). The approach was applied to the dataset comprising taxa present in at least five samples (at least *c*. 5%): on this basis, ten crop categories (Table 6.1) were included (grasspea was left out) using data after proportional re-assignment of indeterminate grain/seed (Section 3.6.3), along with 65 wild taxa (including fruit, nut, tuber group, reed, and wild/weed determinate and indeterminate taxa - Table 6.2). 'Rare' taxa were excluded, not only because they can obscure major trends in the data but also because they may represent chance occurrences (Jones 1991); analyses including all taxa showed that rare ones have little impact on the assemblage (plots not shown).

CROP TAXA	*Name in the correspondence analysis plots*	Ubiquity		Abundance (proportionally re-assigned)
		count	%	
HULLED WHEAT GRAIN	**HWgr**	93	98.94	6950
FREE-THRESHING WHEAT GRAIN	**FTWgr**	26	27.66	352
BARLEY GRAIN	**BARgr**	66	70.21	2416
HULLED WHEAT GLUME BASES	**HWchf**	94	100.00	45015
FREE-THRESHING WHEAT RACHIS	**FTWr**	87	92.55	1299
BARLEY RACHIS	**BARr**	75	79.79	379
LENTIL	**Lens**	67	71.28	45193
PEA	**Pea**	52	55.32	242
CHICKPEA	**Chkpea**	7	7.45	9
BITTER VETCH	**Vetch**	47	50.00	381

Table 6.1 List of crop taxa included in the correspondence analysis

6.1 Variation in the crop and wild content

The distribution and overall crop/wild composition of the 94 samples on the basis of ten crop and 65 wild taxa is shown in Figure 6.1. The contribution of the fruit, nut and tuber group to the sample composition is negligible; in subsequent plots this group of taxa was included with the rest of the wild taxa (i.e. not shown as a separate class).

Figure 6.2 presents the composition of the samples in more detailed terms. The group clustered around the origin consists of 16 *Descurainia*-dominated samples from Building 1 (of which 15 samples were previously recognised, see Sections 4.4.3 and 5.3.1.1). Another three samples from Building 1 also contain relatively high proportions of *Descurainia* seeds but are dominated by crop material and placed further away from the origin. Virtually all of the remaining samples, clustered together towards the positive (right) end of axis 1 and positive (top) end of axis 2, are dominated by hulled wheat or by other wild taxa. A crop-rich outlier in the bottom right part of the plot is the lentil-dominated sample (Fl. 144) from Building 1; removal of this sample from the analysis (plot not shown) revealed another outlier - a wild-rich sample from an oven fill in Building 3 almost entirely composed of *Rumex* seeds (Fl. 5019) - also excluded from further consideration (plot not shown).

Figure 6.3 shows the distribution of 92 samples after removal of the lentil and *Rumex* samples. In addition to the cluster of *Descurainia*-rich samples located near the origin, two other groups of samples are apparent, one comprising samples relatively rich in wild content toward the top end of axis 2, and a larger group located towards the bottom end of axis 2 comprising hulled wheat- and/or wild-rich samples, including the three samples from Building 1 with relatively high *Descurainia* content. In order to explore variation in the sample composition further, the 16 *Descurainia* samples were excluded. This step led to identification of another outlier - a wild-rich pulse sample Fl. 3742 (plot not shown) - which was also removed.

Figure 6.4 plots the remaining 75 samples and shows relative proportions of the crop groups, *Descurainia* and other wild taxa. The group of samples clustered in the bottom left part of the plot is largely dominated by hulled wheat. The two samples with relatively high proportions of *Descurania* are also located to the left but this taxon is not a major influence in this analysis. Instead, on both axes samples dominated by glume bases are contrasted with samples dominated by wild taxa, which, compared to the hulled wheat group, appear scattered due to variable wild content.

The species plot (Figure 6.5) reveals that the wild-rich samples are particularly associated with a suite of taxa including *Aeluropus, Artemisia, Bolboschoenus, Eragrostis, Helianthemum, Juncus,* small-seeded legumes, *Sporobolus* and *Ziziphora.* Seeds of *Bolboschoenus* have been recognised as physically linked to dung remains, while seeds of

other taxa in this group have morphological characteristics that enable potential survival through animal digestion (Section 5.4). Detailed consideration of the distribution of these taxa clarifies the distinction between hulled wheat and wild-rich samples.

Dung-derived plant material

In Chapter 5 several wild taxa were recognised as deriving from animal dung (Table 6.2). In order to explore the effect of dung-derived plant material across the assemblage, the 75 samples were coded by the observed presence of dung (in the form of complete pellets, dung fragments and/or seeds with adhering dung material; Section 5.4.1). Figure 6.6 shows that (28) dung-containing samples are generally distributed, with many occurring among the hulled wheat-dominated samples. Recognisable dung is not especially concentrated in the wild-rich samples at the extreme positive ends of the axes. However, these samples originate from contexts in Space 181 where dung has previously been identified on the basis of calcitic spherulites and/or actual (mineralised) dung pellets (Matthews 1999, 2005a; Fairbairn *et al*. 2005a). The lack of recognisable dung fragments in the (wild-rich) samples from Space 181 analysed here may indicate that dung pellets, once present in the matrix, had disintegrated, releasing seeds (cf. Charles 1998: 113). This hypothesis is supported by the fact that, in the present study, some of the taxa whose seeds were observed in physical association with dung and are considered dung-derived occur in significantly higher proportions in the wild-rich samples compared to the hulled wheat samples (Fig. 6.7), suggesting a greater contribution of residues from dung burning to these deposits. The presence of dung (and taxa sometimes associated with dung) in hulled wheat samples (Fig. 6.8) could be due to the 'mixed' nature of the sampled deposits or, for instance in fire installations, a consequence of the use of dung as fuel together with other sources including crop processing by-products (van der Veen 2007).

In addition to the taxa previously identified as dung-derived based on their physical association with dung (*Bolboschoenus, Carex, Chenopodium, Polygonum, Sporobolus*), several other taxa are found in relatively high numbers in the wild-rich samples but only occasionally present (at low levels) in the hulled wheat samples (Fig. 6.9a-k): *Aeluropus*, *Artemisia, Eragrostis*, *Helianthemum*, *Juncus*, *Ziziphora,* and small-seeded wild legumes. This group of taxa tends to co-occur with the dung-associated material and is also most abundant in the wild-dominated samples, while more or less absent from the hulled wheat group of samples (Fig. 6.10). Based on the consistent co-occurrence of these taxa with others actually observed in dung, and their highest relative abundance in the wild-rich samples, they

TAXA	*Name in the correspondence analysis plots*	Ubiquity		Abundance	Observed in relation to dung	Classification based on fruiting time	HABITAT			Crop processing physical type
		count	%				dry	dry/ wet	wet	
Pistacia terebinthus L.	**Pista**	44	46.81	132						
Bolboschoenus sp.	**BolbTub**	36	38.30	79						
Quercus L.	**Querc**	24	25.53	64						
Amygdalus orientalis L. type	**Amyg**	5	5.32	5						
Prunus divaricata Ledeb. type	**Prudiv**	18	19.15	85						
Prunus L./*Amygdalus* L.	**PruAmyg**	23	24.47	63						
Celtis L.	**Celtis**	52	55.32	503						
indeterminate nut kernels	**nuttub**	8	8.51	11						
Phragmites australis (Cav.) Trin.	**Reed**	49	52.13	173		late			x	
Sporobolus R. Br.	**DSporo**	62	65.96	5151	x	intermediate			x	**SFL**
Bolboschoenus glaucus (Lam.) S.G. Smith	**Dbolb**	93	98.94	10779	x	intermediate			x	SFH
Carex L.	**DCar**	54	57.45	463	x			x		SFH
Chenopodium L.	**DChen**	17	18.09	164	x	late	x			SFH
Polygonum aviculare aggregate	**DPolAv**	76	80.85	1060	x	late	x			SFH
Aeluropus Trin.	**Aelur**	39	41.49	11619	(x)	late			x	**SFL**
Artemisia annua L. type	**Artem**	14	14.89	1724	(x)	late	x			**SFL**
Eragrostis N.M. Wolf	**Erag**	8	8.51	653	(x)	late		x		**SFL**
Juncus L.	**Junc**	27	28.72	3909	(x)	intermediate			x	**SFL**
Helianthemum Adans.	**Helian**	23	24.47	642	(x)	intermediate	x			**SFL**
Leguminosae , small wild	**SLEG**	81	86.17	6346	(x)	intermediate	x			SFH
Ziziphora capitata L./*persica* Bunge	**Zizi**	5	5.32	50	(x)	intermediate	x			SFH
Crypsis aculeata (L.) Aiton type	**DCryps**	11	11.70	380		intermediate			x	**SFL**
Alisma L.	**Alis**	6	6.38	17		intermediate			x	**SFL**
Lemna L.	**Lem**	5	5.32	112		intermediate			x	**SFL**
Eleocharis R. Br.	**Elech**	6	6.38	53		intermediate			x	SFH
Salsola L.	**Sals**	17	18.09	45		late			x	SFH
Taeniatherum caput-medusae L.	**Taen**	68	72.34	617		late	x			BFH
Chenopodium album L. type	**Chealb**	8	8.51	69		late	x			SFH
Heliotropium L.	**Helio**	8	8.51	51		late	x			SFH
Atriplex L.	**Atrplx**	20	21.28	168		late		x		SFH
Rumex L.	**Rum**	23	24.47	559		late		x		SFH
Adonis annua/aestivalis L.	**Adon**	13	13.83	32		early	x			BFH
Boreava orientalis Jaub. & Spach	**Borea**	8	8.51	20		early	x			BFH

Table 6.2 List of wild taxa included in the correspondence analysis and their different classifications

TAXA	*Name in the correspondence analysis plots*	Ubiquity		Abundance	Observed in relation to dung	Classification based on fruiting time	HABITAT			Crop processing physical type
		count	%				dry	dry/ wet	wet	
Cornucopiae cucullatum L. type	**Cornu**	21	22.34	85		early	x			SFH
Conringia orientalis L.	**Conrin**	10	10.64	34		early	x			SFH
Descurainia sophia (L.) Webb	**Desc**	43	45.74	2782177		early	x			SFH
Vaccaria pyramidata Medik.	**Vacc**	29	30.85	89		early	x			SFH
Beta L.	**Beta**	6	6.38	10		early	x			BHH
Buglossoides arvensis L. type	**Bugloss**	27	28.72	102		early	x			
Convolvulus arvensis L. type	**ConvArv**	39	41.49	194		intermediate	x			BFH
Centaurea sp.	**Cent**	12	12.77	31		intermediate	x			BFH
Fumaria L.	**Fum**	5	5.32	10		intermediate	x			BFH
Galium aparine L. type	**GalAp**	32	34.04	92		intermediate	x			BFH
Vicia L./*Lathyrus* L.	**VicLat**	18	19.15	31		intermediate	x			BFH
Androsace L.	**Andro**	5	5.32	39		intermediate	x			SFH
Bromus danthoniae Trin. type	**Brome**	34	36.17	80		intermediate	x			SFH
Eremopyrum (Ledeb.) Jaub. & Spach	**Eremo**	23	24.47	43		intermediate	x			SFH
Sideritis L. type	**Sider**	26	27.66	291		intermediate	x			SFH
Lavatera L. type	**Lava**	12	12.77	14		intermediate	x			BHH
Malva L.	**Malv**	8	8.51	12		intermediate	x			SHH
Silene sp.	**Silen**	20	21.28	214		intermediate	x			SHH
Hordeum murinum L. type	**Hormur**	11	11.70	13		intermediate	x			SHL
Thymelea passerina (L.) Cosson & Germ. type	**Thym**	9	9.57	27		year-round	x			SFH
Campanula L.	**Camp**	7	7.45	7						SFL
Graminae , large	**LGraInd**	66	70.21	323						
Cyperaceae	**CypInd**	40	42.55	599						
Chenopodiaceae	**ChenInd**	36	38.30	478						
Malvaceae	**MalvInd**	33	35.11	83						
Polygonaceae	**PolyInd**	33	35.11	515						
Crucifereae , medium	**MCruc**	22	23.40	248						
Graminae , small	**SGraInd**	16	17.02	207						
Chenopodiaceae/Caryophyllaceae	**CheCar**	13	13.83	75						
Compositae/Dipsacaceae	**ComDip**	9	9.57	15						
Crucifereae , large	**LCruc**	7	7.45	20						
Graminae , medium	**MGraInd**	7	7.45	40						

Table 6.2 - *continued* List of wild taxa included in the correspondence analysis and their different classifications

are considered dung-related and included in the 'suite' of dung-derived species. A large number of *Helianthemum* seeds have been found in a sample from Mellaart's archive (Fairbairn *et al*. 2007) and possible collection for human consumption noted; in the present analysis, however, *Helianthemum* is associated with dung-derived material. All of the taxa in the dung 'suite' have small seeds and/or a hard seed coat, making them potentially resistant to animal digestion (Section 5.4); indeed, they have been found in association with animal dung in other contexts, both at Çatalhöyük (Bogaard *et al.* in press/2013) and elsewhere (e.g. Hastorf and Wright 1998; Charles and Bogaard 2005, 2010).

Overall, the negative relationship between glume bases and certain wild taxa suggests that they derive from different sources, with variable degrees of mixing between them. One possibility is that two different kinds of dung are represented, one rich in glume bases and one dominated by wild taxa. It has been shown experimentally that some glume material can survive goat digestion (Valamoti and Charles 2005), though in a degraded state, while sheep feeding experiments suggests that both cereal chaff and grain have a very low survival rate through the digestive tract (Wallace 2007; Wallace and Charles in press). Given that sheep are the most likely source of the dung pellets (Russell and Martin 2005; Section 7.2.1 below) it appears unlikely that the generally abundant and well preserved glume bases in the assemblage reflect animal diet. A further possibility is that glume bases were sometimes added in the manufacture of dung cakes. At this point, the most secure conclusion as regards dung origin is that taxa physically linked with dung, and other wild taxa that co-occur with them, most probably represent a result of dung burning.

6.1.1 **Crop processing as a cause of variation**

In terms of crop processing stage, the discriminant analysis presented in Chapter 5 classified samples as fine-sieve by-products or as winnowing by-products. Therefore, the first step here was to assess whether the contrast between crop-rich and wild-rich samples could in fact result from the different crop processing stages represented, rather than potential crop processing *vs.* dung origin. Figure 6.11 shows the contribution of wild/weed physical types characteristic of the two relevant stages (Table 6.2): small-free-heavy (SFH), characteristic of the by-products of fine sieving, and small-free-light (SFL), characteristic of the by-products of winnowing; big-free-heavy taxa (BFH), which accompany clean crops in the fine-sieve product, are also shown. Clearly, SFH taxa are widespread, and occur at both ends of axes,

that is, in both crop-rich and wild-rich groups of samples (Fig. 6.12). Many glume base-dominated samples contain significant proportions of SFH taxa, consistent with the inference that glume bases were separated from grain at least in part by fine sieving (Hillman 1981, 1984b; Bogaard 2004a). The levels of SFL taxa are different between the crop- and wild-rich samples, but most of these are small-seeded taxa that would survive sheep digestion, and some of them were observed in dung or belong to the 'dung suite' (*Artemisia, Juncus, Sporobolus, Eragrostis, Helianthemum, Aeluropus*); they are thus unlikely to indicate a genuine contrast in crop processing stage. Other SFL taxa apparently not associated with dung (*Crypsis*, *Alisma*, and *Campanula*) occur in the majority of the hulled wheat samples, but usually at low levels and in lower proportions than SFH taxa. BFH taxa are concentrated in the same area with crops (and majority of the SFH taxa) and they therefore appear specifically related to crop processing/hulled wheat samples. Considered as a by-product of a final (hand-cleaning) stage in the crop-cleaning process, BFH taxa may have been combined with by-products of fine-sieving, e.g. in fire installations, or in stores of 'cleanings' meant for use as fuel/animal feed (Hillman 1981: Fig. 5, 7).

6.1.2 **Ecological causes of variation**

Table 6.2 shows groups of wild/weed taxa defined on the basis of their ecological characteristics considered in Chapter 5 (as part of the assessment of their potential dung-derivation).

Seasonality

The composition of the 75 samples in terms of seasonality/flowering-fruiting time (see Section 5.4.2.2) is presented in Figure 6.13, and the distribution of taxa coded by seasonality categories in Figure 6.14. 'Early' taxa, producing seed before and/or during the likely time of the cereal harvest, but not later, are associated with crop taxa and concentrated in the crop-rich samples. The particularly high proportions of early taxa in two samples (Fig. 6.13) represent *Descurainia* (the samples come from Building 1 where other *Descurainia*-rich deposits were discovered; Section 4.4.3). None of the early taxa forms part of the dung suite (Table 6.2); furthermore, with the exception of *Beta*, they are all of BFH or SFH seed type which, as mentioned above, probably reflect by-products of final stages of crop cleaning that were routinely combined in domestic fires. Based on seasonality and a plausible association with the glume base samples, early taxa are likely of arable origin.

'Late' taxa start flowering/fruiting around harvest time and continue fruiting after this period; they may therefore have a post-harvest origin (e.g. dung of summer-grazing sheep), though an arable harvest origin cannot be excluded *a priori*. It is worth noting that five out of 11 late taxa are considered dung-derived (Table 6.2). Seeds of late taxa are relatively frequent in the assemblage and are generally distributed, as shown in the seasonality species plot (Fig. 6.14); however, they are present in significant proportions only in a few wild-rich samples (Fig. 6.13), particularly the dung-associated taxa - *Artemisia, Aeluropus* and *Eragrostis* (see above).

'Intermediate' taxa have an extended flowering/fruiting period: their seeds can mature before, during and after harvest time. They are the most common group in the samples and are generally distributed (Fig. 6.13-14). Intermediate taxa highly abundant in some of the wild-rich samples (*Bolboschoenus, Sporobolus,* small-seeded legumes) are part of the dung-derived suite (see Table 6.2).

Habitat

In Chapter 5 all wild taxa were classified according to their habitat preferences into three groups: dryland, dryland/wetland and wetland taxa (Table 6.2). Figures 6.15-16 present relative amounts in the samples of taxa from different habitat groups and the distribution of the classified taxa, respectively. Some wild-rich samples contain significant proportions of wet-loving taxa; as shown in Table 6.2, four of the dung-derived taxa grow in wet conditions, and another two can thrive in both wet and dry environments. In fact, most of the wetland taxa in the assemblage (4 out of 6) appear to be dung-derived; the only two associated with hulled wheat samples (Fig. 6.16) are *Alisma* and *Crypsis,* both of which could also be dung-derived: the latter has been observed embedded in dung in the mid-late Neolithic contexts at Çatalhöyük (Bogaard *et al*. in press/2013; A. Bogaard, M. Ergun, pers. comm.). *Alisma* is an aquatic plant and unlikely to occur in arable fields; it could have been ingested by animals with drinking water.

Dryland taxa are generally distributed across the assemblage, but are dominant in the lower left part of the plot, in hulled wheat samples. The taxa intermediate in terms of habitat type are also scattered throughout the left side of the plot; a single intermediate taxon at the top of axis 2 is a dung-derived small-seeded grass *Eragrostis*.

6.1.3 **Archaeological context of the samples**

Brief descriptions of the archaeological contexts of the samples analysed are given in Section 3.3.2. Table 6.3 summarises context information for the 75 samples and lists sample classes used in the correspondence analysis. Figure 6.17 shows the 75 samples coded according their archaeological context; in Figure 6.18 the samples are classified according to the character of deposition (and implied spatial and temporal resolution - cf. Miksicek 1987; Schiffer 1987): a) primary (i.e. material burnt *in situ* or found adjacent to fire installations – ashy spread, rake-out), and/or b) secondary (and tertiary) contexts (e.g. midden, pit/cut/building fill). Figure 6.19 shows samples classified based on their location (inside/outside structures) and Figure 6.20 combines context (primary/secondary) and location (indoor/outdoor) of the samples. Bin/basin fill is regarded a primary deposit only if evidence of *in situ* burning was encountered; a single basin fill sample (Fl. 135) from Building 1 satisfies this criterion (see Table 6.3).

Hulled wheat samples come from a range of archaeological context types, demonstrating continuity in composition among some primary and secondary deposits. Primary deposits dominated by hulled wheat glume bases originate from burning-related features inside buildings; hulled wheat-rich secondary deposits come from non-primary bin/basin fills, middens, penning deposits and pit/cut/building fills (Fig. 6.20). The similar composition of the hulled wheat-dominated primary and secondary deposits probably means that internally generated dehusking by-products (glume bases and weed seeds) were cleaned out of fire installations (where combined with dung fuel and/or wood), smeared across internal floors and re-deposited in middens, from which material could be quarried for further tertiary deposition (e.g. in filling, repairing, floor packing etc; Martin and Russell 1996; Fairbairn *et al*. 2005a; Farid 2007). Such processes would explain the concentration of generally mixed midden/midden-like deposits and indoor contexts in the same area of the plot.

Wild-rich samples derive from two types of *primary* context (Fig. 6.20): fire installations (indoor structures) and external burning events (fire spots). Since wild-rich samples are mostly composed of dung-derived material, this could indicate that dung was burnt intensively in both external (fire spots) and in (at least some) internal fire-related features, yielding a similar dung ‘signature’ in both indoor and outdoor areas.

	Sample number	Summarised context type	Deposition	Location	Building/ Space	Chronology (area/phase)	Classification in correspondence analysis	Crop processing classification (by-product)
1	2326	ashy spread	primary	indoor	2/117	South K	hulled wheat	Winnowing
2	3399	ashy spread	primary	indoor	3/86	North G	hulled wheat	Winnowing
3	1795	ashy spread	primary	indoor	3/86	North G	hulled wheat	Fine sieve
4	2792	ashy spread	primary	indoor	6/173	South L	hulled wheat	Fine sieve
5	2474	ashy spread	primary	indoor	16/164	South K	hulled wheat	Fine sieve
6	26-37.38	ashy spread	primary	indoor	18/171	South J	hulled wheat	Fine sieve
7	2661	ashy spread	primary	indoor	18/171	South J	hulled wheat	Fine sieve
8	3026	ashy spread	primary	indoor	23/178	South J	hulled wheat	Fine sieve
9	135	bin/basin	primary (burnt building)	indoor	1/188	North G	hulled wheat	Winnowing
10	813	bin/basin	secondary (no burning)	indoor	2	South K	hulled wheat	Winnowing
11	1950	bin/basin	secondary (no burning)	indoor	5/157	North F?	hulled wheat	Winnowing
12	2425	bin/basin	secondary (no burning)	indoor	6/163	South L	hulled wheat	Winnowing
13	1735	bin/basin	secondary (no burning)	indoor	2	South K	hulled wheat	Fine sieve
14	4714	bin/basin	secondary (no burning)	indoor	3/201	North G	hulled wheat	Fine sieve
15	4732	bin/basin	secondary (no burning)	indoor	3/201	North G	hulled wheat	Fine sieve
16	5030	bin/basin	secondary (no burning)	indoor	3/201	North G	hulled wheat	Fine sieve
17	1791	bin/basin	secondary (no burning)	indoor	5/157	North F?	hulled wheat	Fine sieve
18	2763	bin/basin	secondary (no burning)	indoor	6/173	South L	hulled wheat	Fine sieve
19	27-13.15	bin/basin	secondary (no burning)	indoor	18/172	South J	hulled wheat	Fine sieve
20	539.551	fill	secondary	indoor	1/186	North G	hulled wheat	Winnowing
21	2985	fill	secondary	indoor	6/173	South L	hulled wheat	Winnowing
22	1010	fill	secondary	indoor	4	South L	hulled wheat	Fine sieve
23	2535	fill	secondary	indoor	6/163	South L	hulled wheat	Fine sieve
24	232	fill	secondary	indoor	105	South M	hulled wheat	Fine sieve
25	2439	fill	secondary	indoor	160	South N?	hulled wheat	Fine sieve
26	3499	fill	secondary	indoor	natural	Unassigned	hulled wheat	Fine sieve
27	520	fire installation	primary	indoor	1/187	North G	HW/Descurainia	Fine sieve
28	395	fire installation	primary	indoor	1/183	North G	HW/Descurainia	Winnowing
29	465	fire installation	primary	indoor	1/187	North G	HW/Descurainia	Winnowing
30	4361	fire installation	primary	indoor	3/158	North G	hulled wheat	Winnowing
31	3338	fire installation	primary	indoor	23/200	South J	hulled wheat	Winnowing
32	904	fire installation	primary	indoor	109	South M	hulled wheat	Winnowing
33	5176	fire installation	primary	indoor	3/201	North G	hulled wheat	Fine sieve
34	3247	fire installation	primary	indoor	17/170	South K	*wild-rich*	Fine sieve
35	3546	fire installation	primary	indoor	23/178	South J	*wild-rich*	Fine sieve
36	940	fire installation	primary	indoor	112	South M	hulled wheat	Fine sieve
37	3297	fire spot	primary	outdoor	181	South G	*wild-rich*	Winnowing
38	3324	fire spot	primary	outdoor	181	South G	*wild-rich*	Winnowing
39	3351	fire spot	primary	outdoor	181	South G	*wild-rich*	Winnowing

Table 6.3 List of samples for the correspondence analysis showing their archaeological context and classifications

	Sample number	Summarised context type	Deposition	Location	Building/ Space	Chronology (area/phase)	Classification in correspondence analysis	Crop processing classification (by-product)
40	3666	fire spot	primary	outdoor	181	South G	*wild-rich*	Winnowing
41	3742*****	fire spot	primary	outdoor	181	South G	*wild-rich*	Winnowing
42	31-27.33.37	fire spot	primary	outdoor	181	South G	*wild-rich*	Fine sieve
43	31-48.49.51	fire spot	primary	outdoor	181	South G	hulled wheat	Fine sieve
44	830	midden	secondary	outdoor	2	South K	hulled wheat	Winnowing
45	1804	midden	secondary	outdoor	115	South L	hulled wheat	Winnowing
46	345	midden	secondary	outdoor	2	South K	hulled wheat	Fine sieve
47	513	midden	secondary	outdoor	2/116	South K	hulled wheat	Fine sieve
48	588	midden	secondary	outdoor	2	South K	hulled wheat	Fine sieve
49	639	midden	secondary	outdoor	2	South K	hulled wheat	Fine sieve
50	674	midden	secondary	outdoor	2	South K	hulled wheat	Fine sieve
51	4545.4626	midden	secondary	outdoor	85	North G	hulled wheat	Fine sieve
52	4741	midden	secondary	outdoor	85	North G	hulled wheat	Fine sieve
53	128	midden	secondary	outoor	115	South L	hulled wheat	Fine sieve
54	173	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
55	192	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
56	198	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
57	295	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
58	366	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
59	677	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
60	1038	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
61	1297.164	midden	secondary	outdoor	115	South L	hulled wheat	Fine sieve
62	281	midden	secondary	outdoor	107/108	South M	hulled wheat	Fine sieve
63	2236	penning	secondary	outdoor	2/117	South K	hulled wheat	Winnowing
64	1156	penning	secondary	outdoor	2/117	South K	hulled wheat	Fine sieve
65	31-04.06.07	penning	secondary	outdoor	199	South H	hulled wheat	Fine sieve
66	1217	rake out	primary	indoor	2	South K	hulled wheat	Fine sieve
67	3099	rake-out	primary	indoor	6/173	South L	hulled wheat	Winnowing
68	2576	rake-out	primary	indoor	18/171	South J	hulled wheat	Winnowing
69	25-94.95.96	rake-out	primary	indoor	18/171	South J	hulled wheat	Winnowing
70	26-25.36	rake-out	primary	indoor	18/171	South J	hulled wheat	Fine sieve
71	2679	rake-out	primary	indoor	18/171	South J	hulled wheat	Fine sieve
72	1579	roof	secondary	outdoor	3/86	North G	hulled wheat	Winnowing
73	1631	roof	secondary	outdoor	3/86	North G	hulled wheat	Winnowing
74	16-31.49.64.1732	roof	secondary	outdoor	3/86	North G	hulled wheat	Winnowing
75	1669	roof	secondary	outdoor	3/86	North G	hulled wheat	Winnowing
76	1853	roof	secondary	outdoor	3/86	North G	hulled wheat	Fine sieve

***** - included in wild-only analysis

Table 6.3 - *continued* List of samples for the correspondence analysis showing their archaeological context and classifications

The roof samples appear 'intermediate' in terms of their composition, being distributed between the two apparent extremes - external (wild-rich) primary deposits (i.e. fire spots) and internal (hulled wheat-rich) primary contexts. This relative position suggests that some internal activities (documented on the 'ground floor' of houses) took place on the roof, as also indicated by finds of fragmented fire installation (oven) within the roof collapse detected in Building 3 (Stevanović and Tringham 1998; Matthews 2012).

It is worth noting that the three samples from penning deposits (two from Space 117 and one from Space 199) are concentrated in the hulled wheat zone of the plot. Indeed they resemble other hulled wheat samples in that they are rich in glume bases and contain very little wild material. The mineralised *Bolboschoenus* seeds found in one of the Space 199 samples indicate high mineral content of the sediment characteristic of animal pens, and they probably derive from animal faeces, though dung was not identified in the penning samples analysed in this study. The lack of *in situ* burning in these locations means that the charred plant material arrived from elsewhere (e.g. fire installations, middens) and does not represent primary deposition (cf. Fairbairn *et al*. 2005a: 153). Based on the composition, it is likely that the content of these samples represents a mixture from a range of sources, similar to midden deposits (cf. Fairbairn *et al*. 2005a: 153).

Figure 6.21 shows the excavation area from which the samples originate; Figure 6.22 codes the 75 samples by Building or Space. Five of the seven wild-rich samples were recovered from fire spots in external Space 181 in the South Area; the two other wild-rich samples come from fire installations in Buildings 17 and 23 in the South Area. With the exception of these, and the samples from Building 1 (clustered along the top end of axis 2), deposits from other buildings/spaces appear similar in composition and are relatively rich in hulled wheat glume bases. The apparent distinction between the South and North areas is understood as a product of the availability of the samples for the study, since the primary *external* contexts (fire spots) derive only from the South Area. The distribution of the samples in the plot does, however, reflect the emerging difference in the composition between primary *external* contexts and primary *internal* contexts (here mostly consisting of samples from the North Area).

The chronological attribution of the 75 samples is shown in Figure 6.23. Wild-rich samples belong to lower (early) phases of occupation in the South Area; all fire spot samples come from the earliest recorded phase in the South Area. Other samples from 'South' phases are

concentrated in the hulled wheat area of the plot at the left end of axis 1, along with samples from structures in the North Area (with the exception of Building 1 samples), suggesting their similar taphonomic histories.

6.2 Variation in the assemblage based on the wild content only

In order to fully explore variation in the wild content of the samples, particularly in terms of the potential contribution of harvest-derived arable weeds versus dung-derived forage material, all crop categories were removed from the analysis. As above (Section 6.1), wild taxa occurring in less than five samples were automatically excluded from consideration (leaving a total of 65 taxa; Table 6.2). In order to simplify investigation of the 'behaviour' of the taxa represented by charred wild/weed seeds, which make up the bulk of the wild content, the following groups of taxa were excluded from further analysis: those represented by mineralised remains (*Buglossoides, Lithospermum, Lemna, Eleocharis*), and fruit, nut and tuber taxa; 53 taxa remained for inclusion. An initial analysis again revealed clustering of the 16 *Descurainia*-rich samples and, after their removal, the two previously recognised outliers - lentil sample (Fl. 144) and *Rumex* sample (Fl. 5019), plus a 'new' outlier - Fl. 4361 (from a fire installation in Building 3) rich in *Crypsis* seeds, emerged. Their exclusion (plots not shown) left 75 samples for the analysis.

Figure 6.24 shows the distribution of the 75 samples, with sample points coded to indicate their classification as wild- versus glume base-rich samples in the previous analysis (Section 6.1); the previously outlying and excluded pulse sample Fl. 3742 is included as wild-rich (see Section 4.3.3). Wild-rich samples are concentrated toward the bottom of axis 2 (Fig. 6.24), as are most of the dung-derived taxa, as shown in Figure 6.25 (species plot). Figure 6.26 shows the relative quantities of different wild/weed categories; the 'dung suite' dominates the wild content of the majority of samples, whereas *Descurainia* and other wild/weed taxa occur in high proportions in the 'non-dung' group of samples at the top of axis 2 (see also Fig. 6.27). In conclusion, there exists a clear trend along axis 2, from dung-derived material at the bottom of the axis, to crop-related components of the assemblage at its top. Thus, the contrast between 'dung' and 'crop' samples observed in the previous analysis persists when crops are removed.

Figures 6.28 and 6.29 present relative abundances of the different crop processing-related seed types and their distribution across the samples, respectively. In Figure 6.30 the samples are coded by their crop processing classification in the discriminant analysis. There is a weak tendency for SFL taxa to increase toward the bottom of axis 2 and they are most abundant in the wild-rich samples; as shown above (Section 6.1), most SFL taxa are dung-derived and their patterning is not perceived as relevant to crop processing. SFH taxa are generally distributed, suggesting that axis 2 does not relate to 'genuine' differences in crop processing stage of the samples.

Figure 6.31 shows relative quantities of the different seasonality (flowering/fruiting time) categories of the taxa, and Figure 6.32 reveals their distribution among the samples. The 'early' taxa, more or less associated with crops in the previous analysis (Section 6.1), are most abundant in the samples at the top of axis 2, especially *Descurainia* which, while it could have grown in and around crop fields as a weed/ruderal, at Çatalhöyük was most probably a collected plant and not a by-product of crop processing (Section 4.4). Other seasonality-based categories appear to have similar proportions across the assemblage; this is somewhat different to the situation encountered in the 'crop and wild' analysis, where 'late' taxa appeared most abundant in some wild-rich samples (Fig. 6.13).

Figures 6.33-34 show proportions and distributions of the taxa classified by habitat wetness. It was determined earlier (Section 6.1) that the majority of the wetland taxa derive from dung (see Table 6.2); two other dung taxa (*Carex* and *Eragrostis*) can also thrive in damp areas. Wet-loving plants dominate the majority of the wild-rich/dung samples; in the plot they occupy the lower part of axis 2. The distinct group of crop-rich samples at the top of axis 2 is mainly composed of dryland taxa, a trend which was less apparent in the crop-and-wild analysis (Fig. 6.15).

Figures 6.35-37 present aspects of the archaeological context of the samples. As already noted the 'extreme' wild-rich samples, almost entirely composed of dung-derived taxa, come from external primary contexts (fire spots) in Space 181 and so appear to represent evidence of outdoor dung burning. The rest of the 'dung' samples in the lower part of the plot derive from a range of contexts, primary and secondary, indoor and outdoor (e.g. fire installations, midden), implying a general mixing of different material, burnt and preserved indoors or subsequently disposed of outdoors.

By contrast, samples of the 'non-dung' group originate exclusively from indoor contexts (Fig. 6.38), both primary (fire installations, burnt basin fill from Building 1) and secondary (non-*in situ*-burnt bin/basin fills). Roof samples occupy an intermediary position, as already seen in previous analysis.

The distribution in the plots of buildings and spaces from which the samples originate (Figs. 6.39-41) shows that, non-dung samples derive from the three analysed buildings in the North Area, while dung-rich samples come mainly from the South Area buildings and spaces. Interestingly, micromophological analysis of Building 3 revealed a lack of dung in indoor deposits (Matthews 2012). As already pointed out, the apparent distinction between the samples based on the excavation area (and 'early'/'late' occupation levels) is at least in part a result of the lack of fire spot samples from the North Area.

The exclusion of *Descurainia*

Descurainia was likely a collected source and may exaggerate the dung versus non-dung distinction among wild taxa. In order to securely distinguish between wild taxa originating as arable weeds and taxa brought in through dung use, the analysis based on wild taxa was repeated without *Descurainia*.

Removal of *Descurainia* left three samples with less than 30 items, which were therefore eliminated from further analysis. Altogether, 72 samples and 52 taxa were entered in the analysis. Figure 6.42 shows that there are no significant changes in distribution of the samples along the axes after the exclusion of *Descurainia* (compare with Fig. 6.24). The species plot in Figure 6.43 (with indicated 'dung suite') shows that the majority of the dung taxa remain clustered in the lower part of the plot; the habitat trend along axis 2 noted above also remains clear (Fig. 6.44-45).

Figure 6.46 shows the distribution of samples classified according to the archaeological context type; Figure 6.47 combines information on indoor/outdoor location and primary/secondary deposition. Figure 6.48 presents building/space data for the samples; in Figure 6.49 the samples are coded based on the excavation area and in Figure 6.50 they are coded according to the assigned chronological phase.

The samples concentrated at the top end of axis 2 belong to the same previously recognised group of samples dominated by non-dung/dryland taxa (see Fig. 6.26-6.28), and containing small to moderate amounts of taxa observed in dung. They represent primary (fire-related contexts and an *in situ* burnt basin fill) and secondary indoor contexts (bin/basin fills) in the North Area (Buildings 1, 3 and 5). The samples at the far opposite end of axis 2 represent dung-rich samples from primary outdoor contexts (fire spots) in the South Area, dominated by dung-derived/wetland taxa. The apparent distinction between North and South area samples (Fig. 6.49) noted before the exclusion of *Descurainia*, persists after its removal and could again be explained by the lack of North Area fire spots among the samples included in the analysis. It appears that the North Area samples are less 'affected' by dung since, for example, primary/indoor South Area samples (coming from fire installations, rake-outs, ashy spreads) are located toward the lower (dung-) end of the plot (i.e. more closely resembling fire spot samples), whereas samples from the same context types in the North Area are located toward the top end of the plot. The contrast could perhaps be supported by the micromorphological evidence from Building 3, pointing to the general lack of dung-containing deposits inside the building. It should be borne in mind, however, that the North Area yielded samples from a unique burned building (Building 1), and no comparable dataset from the South Area was included in the analysis (in terms of primary/high-resolution character of the deposits). At present, therefore, the apparent distinction between the two excavation areas is doubtful, and more data are required to explore it further.

6.3 Summary and conclusions

The correspondence analysis of crop and wild taxa in the assemblage (Section 6.1) confirmed the previously established sample classification and provided a means of exploring contrasts between the two major groups, hulled wheat (glume base) samples and wild-dominated samples. The results suggest that the two groups differ in their wild plant composition. Several of the previously observed dung-associated taxa dominate the wild-rich samples and co-occur with another group of taxa that may also be dung-derived. The ecological characteristics of these taxa are distinctive (Table 6.2). In terms of fruiting time they are 'intermediate' or 'late', meaning that their seed production period includes but also extends beyond harvest time. In terms of habitat they are potentially or exclusively wetland species, unlike most other identified wild taxa. Their repeated co-occurrence and their significantly

high relative and absolute abundance in the samples with very little other wild and/or crop material point to a single 'route of entry' for these species, most likely burning of animal dung. Moreover, the wild-rich/dung samples derive from primary contextual locations, where little or no mixing of deposits/material has occurred, and thus they preserve the original signature of the respective events/activities.

While important differences have emerged between dung-rich and 'dung-poor' samples in their wild content, the overwhelming dominance of hulled wheat glume bases in the majority of the samples potentially affects such contrasts. In order to eliminate the obscuring effect of glume bases, another sequence of analyses was based only on the wild content of the samples (Section 6.2); the results corroborated the observations made in Section 6.1.

The cluster of wild-dominated samples noted earlier remains distinct and is characterised by the dung-derived 'suite'. The marked differentiation between dung-rich and dung-poor samples does not change after the exclusion of *Descurainia*, which is regarded a collected resource. With few exceptions, the dung-rich samples derive from a range of contexts in the South Area of the East mound, indicating a widespread use of dung as fuel. The distinctive group of samples at the top of axis 2 originates from internal structures in the North Area and has very low relative quantities of dung-derived material. These samples are dominated by a 'set' of wild taxa in many ways different to that in dung-samples: a) these taxa do not occur or are present in very small numbers in dung-samples, b) their physical properties relate to final stages of crop-processing, and c) the specific flowering/fruiting time (and habitat type) points to their likely arable weed status. The two dung-derived taxa present in 'non-dung' samples - *Polygonum* and *Chenopodium* - are common cereal stubble weeds (Ellenberg 1988) and, therefore, suggest an additional aspect of livestock diet to the one implied by wet-loving taxa, i.e. (sheep) stubble grazing, perhaps indicating different grazing/foddering regimes across the site. It is also possible that some 'non-dung' taxa in some instances enter the site via stubble grazing, in addition to their crop processing route. Regardless of their 'mode of arrival', they represent arable flora and are relevant to the study of crop growing conditions and practices.

Overall, the variation in the assemblage was explored using previously established criteria and sample classifications. The correspondence analysis offered a basis for clear separation of dung and arable weed 'signals' in the assemblage. The two datasets form the foundation for investigations into animal and crop husbandry, presented in Chapter 7.

Chapter 7 Animal and crop husbandry at Çatalhöyük

Previous chapters have provided an overview of the crop and wild taxa in the assemblage and their frequencies (Ch. 4), considered the major plant-related formation processes that shaped the assemblage (Ch. 5), and explored variability in the composition of the samples, particularly in terms of the contribution of different activities and sources (Ch. 6). The aim of this chapter is to use available ecological and biological data on the wild/weed component of the assemblage to investigate in greater detail the nature of two major aspects of 'off-site' land use: animal herding and crop cultivation.

7.1 Arable *vs*. non-arable wild/weed evidence – a summary

Chapter 5 positively identified dung-derived plant remains in the assemblage based on a series of criteria proposed by Charles (1998). In the correspondence analysis presented in Chapter 6 these taxa were consistently accompanied by other wild taxa with similar morphological attributes (e.g. size), flowering time and habitat. As shown in Sections 6.1 and 6.2, it is clear that the taxa observed in dung and the taxa associated with them form a coherent group inversely correlated with crop (and *Descurainia*) content. The remaining wild taxa are potential indicators of the arable environment; they occur mainly in the samples with little to no dung content, their physical properties relate to late stages of crop-processing, and their flowering/fruiting time (and habitat type) points to their likely arable weed status.

Correspondence analysis distinguished between samples dominated by dung and those characterised by potential weed taxa associated with crop remains, especially hulled wheat glume bases. Crop processing was certainly a major source of the material in these chaff-dominated samples. Other possible taphonomic pathways for the glume material, such as use of crop processing by-products as fodder, or as temper in dung cake manufacture (cf. Charles 1998; Limbrey 2010), appear unlikely on the whole given the striking disassociation of glume bases and dung-derived material, as well as the remarkably high number of well preserved glume bases in these samples (Valamoti and Charles 2005; Wallace 2007; Wallace and Charles in press). On the other hand, it is quite possible that crop processing by-products were used as fuel on their own (cf. Hillman 1981, 1984b; Jones 1984; van der Veen 2007), and that

they became mixed to varying degrees with material derived from dung (cakes) burnt in fire installations (cf. Bottema 1984; Reddy 1997).

Building upon the observations made in Chapters 5 and 6, Table 7.1 classifies the wild/weed taxa in terms of the on-site activities (dung burning versus crop processing) and land use practices (animal husbandry versus crop cultivation) that they represent; 42 taxa occur in at least 5 samples (*c*. 5%; see Table 4.6a) and are represented as charred seeds in the assemblage (non-charred and non-seed remains are left out). The majority of dung-derived taxa occur in very large proportions in the wild-rich samples concentrated at the bottom of axis 2 (the 'dung-end') in the wild-based correspondence analysis (Fig. 6.24-26, 6.42-43). The status of rare taxa (i.e. occurring in fewer than 5 samples) was established based on their similarity with the frequent taxa in ecological characteristics (seasonality and habitat) and seed morphology (size, hardiness of seed coat - Section 5.4).

A continuum from dung-dominated to hulled wheat-dominated samples observed in the correspondence analysis (Sections 6.1-2) can be interpreted as non-arable to arable continuum, reflecting different sources of the material as well as different activities and, to some extent, parts of the landscape (see below). The following sections present detailed data on the biological and ecological background of the two groups of wild taxa and discuss their implications for the reconstruction of crop and animal husbandry.

7.2 **Animal husbandry**

Çatalhöyük faunal evidence shows that domestic caprines, primarily sheep, constitute the most common faunal taxon throughout the early-middle (and later) Neolithic occupation of the site (Russell and Martin 2005; Russell *et al*. in press/2013). In addition to the primary analysis of faunal remains, different approaches have contributed to the study of animal husbandry: dental microwear (Henton 2010, 2012, in press/2013), bone chemistry/stable isotopes (Richards and Pearson 2005; Pearson *et al*. 2007; Henton 2010, 2012, in press/2013) and soil micromorphology (Matthews 2005a, 2010). These sources provide complementary perspectives on the diet of Çatalhöyük sheep. For instance, sequential sampling of tooth enamel from the second molars of sheep enabled measurement of oxygen stable isotope ratios and hence provided information on annual herd movement relevant to e.g. food sources

Taxa	Inferred origin	Ubiquity		Abundance	Name in the plots
		count	%		
Descurainia sophia (L.) Webb	*collected*	*43*	*45.74*	*2782177*	*Desc*
Bolboschoenus glaucus (Lam.) S.G. Smith	dung-derived	*93*	*98.94*	*10779*	*DBolb*
Leguminosae , small wild	dung-derived	*81*	*86.17*	*6346*	*SLEG*
Polygonum aviculare aggregate	dung-derived	*76*	*80.85*	*1060*	*DPolAv*
Sporobolus R. Br.	dung-derived	*62*	*65.96*	*5151*	*DSporo*
Carex L.	dung-derived	*54*	*57.45*	*463*	*DCar*
Aeluropus Trin.	dung-derived	*39*	*41.49*	*11619*	*Aelur*
Juncus L.	dung-derived	*27*	*28.72*	*3909*	*Junc*
Helianthemum Adans.	dung-derived	*23*	*24.47*	*642*	*Helian*
Salsola L.	dung-derived	*17*	*18.09*	*45*	*Sals*
Chenopodium L.	dung-derived	*17*	*18.09*	*164*	*DChen*
Artemisia annua L. type	dung-derived	*14*	*14.89*	*1724*	*Artem*
Eragrostis N.M. Wolf	dung-derived	*8*	*8.51*	*653*	*Erag*
Heliotropium L.	dung-derived	*8*	*8.51*	*51*	*Helio*
Beta L.	dung-derived	*6*	*6.38*	*10*	*Beta*
Ziziphora capitata L./*persica* Bunge	dung-derived	*5*	*5.32*	*50*	*Zizi*
Taeniatherum caput-medusae L.	non-dung/arable	*68*	*72.34*	*617*	*Taen*
Convolvulus arvensis L. type	non-dung/arable	*39*	*41.49*	*194*	*ConvArv*
Bromus danthoniae Trin. type	non-dung/arable	*34*	*36.17*	*80*	*Brome*
Galium aparine L. type	non-dung/arable	*32*	*34.04*	*92*	*GalAp*
Vaccaria pyramidata Medik.	non-dung/arable	*29*	*30.85*	*89*	*Vacc*
Sideritis L. type	non-dung/arable	*26*	*27.66*	*291*	*Sider*
Eremopyrum (Ledeb.) Jaub. & Spach	non-dung/arable	*23*	*24.47*	*43*	*Eremo*
Rumex L.	non-dung/arable	*23*	*24.47*	*559*	*Rum*
Cornucopiae cucullatum L. type	non-dung/arable	*21*	*22.34*	*85*	*Cornu*
Atriplex L.	non-dung/arable	*20*	*21.28*	*168*	*Atrplx*
Silene sp.	non-dung/arable	*20*	*21.28*	*214*	*Silen*
Vicia L./*Lathyrus* L.	non-dung/arable	*18*	*19.15*	*31*	*VicLat*
Adonis annua/aestivalis L.	non-dung/arable	*13*	*13.83*	*32*	*Adon*
Lavatera L. type	non-dung/arable	*12*	*12.77*	*14*	*Lava*
Centaurea sp.	non-dung/arable	*12*	*12.77*	*31*	*Cent*
Hordeum murinum L. type	non-dung/arable	*11*	*11.70*	*13*	*Hormur*
Conringia orientalis L.	non-dung/arable	*10*	*10.64*	*34*	*Conrin*
Thymelea passerina (L.) Cosson & Germ. type	non-dung/arable	*9*	*9.57*	*27*	*Thym*
Malva L.	non-dung/arable	*8*	*8.51*	*12*	*Malv*
Boreava orientalis Jaub. & Spach	non-dung/arable	*8*	*8.51*	*20*	*Borea*
Chenopodium album L. type	non-dung/arable	*8*	*8.51*	*69*	*Chealb*
Fumaria L.	non-dung/arable	*5*	*5.32*	*10*	*Fum*
Androsace L.	non-dung/arable	*5*	*5.32*	*39*	*Andro*
Crypsis aculeata (L.) Aiton type	possibly dung-derived	*11*	*11.70*	*380*	*DCryps*
Campanula L.	possibly dung-derived	*7*	*7.45*	*7*	*Camp*
Alisma L.	possibly dung-derived	*6*	*6.38*	*17*	*Alis*
RARE TAXA					
Chenopodium chenopodioides L. type	possibly dung-derived	*3*	*3.19*	*4499*	
Potamogeton L.	possibly dung-derived	*1*	*1.06*	*1*	
Suaeda L.	possibly dung-derived	*1*	*1.06*	*8*	
Teucrium L.	non-dung/arable	*4*	*4.26*	*21*	
Hordeum spontaneum C. Koch type	non-dung/arable	*4*	*4.26*	*7*	
Polygonum convolvulus L.	non-dung/arable	*4*	*4.26*	*4*	
Galium verum L. type	non-dung/arable	*3*	*3.19*	*43*	
cf. *Lallemantia peltata* L.	non-dung/arable	*3*	*3.19*	*5*	
Anagallis L.	non-dung/arable	*2*	*2.13*	*7*	
cf. *Potentilla* L. type	non-dung/arable	*2*	*2.13*	*3*	
Ranunculus L.	non-dung/arable	*2*	*2.13*	*2*	
Erodium L'Hérit.	non-dung/arable	*2*	*2.13*	*2*	
Valerianella Miller	non-dung/arable	*2*	*2.13*	*3*	
Verbena officinalis L.	non-dung/arable	*2*	*2.13*	*8*	
Papaver L.	non-dung/arable	*1*	*1.06*	*2*	
Capsella Medik.	non-dung/arable	*1*	*1.06*	*1*	
Euphorbia L.	non-dung/arable	*1*	*1.06*	*2*	
Geranium L., small type	non-dung/arable	*1*	*1.06*	*1*	
Viola L.	non-dung/arable	*1*	*1.06*	*1*	
Linum L.	non-dung/arable	*1*	*1.06*	*13*	
Polygonatum Miller	non-dung/arable	*1*	*1.06*	*9*	
cf. *Secale* sp.	non-dung/arable	*1*	*1.06*	*1*	
Stipa L.	non-dung/arable	*1*	*1.06*	*20*	

Table 7.1 The origin of wild/weed taxa in the assemblage

during the first year of life (the enamel precipitation period); dental microwear indicated the type of animal diet in the final (pre-slaughter) part of their life (a few days before death). Previous archaeobotanical analysis has provided information on the vegetation potentially available for livestock feeding, while stable carbon and isotope values revealed considerable variability in caprine diets suggested by the input of C3 and C4 plants (Fairbairn *et al*. 2005a; Pearson *et al*. 2007). The archaeobotanical analysis presented here has identified the actual remains of animal diet - charred plant material recognisable as deriving from sheep dung, allowing more precise identification of the components of diet and insight into animal feeding patterns, with broader implications for herd management and land use (cf. Charles and Bogaard 2005, 2010).

A summary of the results of faunal analysis relevant to the study of sheep/(goat) husbandry and diet is given in the section below, followed by presentation and discussion of new archaeobotanical data obtained through the current work, with references to the conclusions from previous analysis (Fairbairn *et al*. 2005a).

7.2.1 **Faunal and isotope evidence of sheep (and goat) herding**

The faunal evidence reveals that domestic sheep were kept from the earliest occupation phases (Pre-Level XII/South G) as well as, in much lower numbers, domestic goats (Russell and Martin 2005), demonstrating that the site was founded on a package of sheep and goat herding combined with cultivation of a range of cereals and pulses. Mortality assessment (based on bone fusion data) suggest that sheep (and goat) were kept mainly for meat, males being killed primarily as juveniles and young adults (the optimal time for meat yield) and females surviving longer (Russell and Martin 2005). The ageing data available from analysis of dental eruption and wear also demonstrate emphasis on culling of the animals as older infants and juveniles (peek culling between one and two years of age), sub-adults and early adults (Russell and Martin 2005). Older animals could have been reared for breeding, though due to their higher fat content they might have also been considered for slaughter (Henton in press/2013). Based on the extended slaughter period over a few years, from the age of six months to up to around three years, it is proposed that there was enough food (graze and/or fodder) to sustain animals beyond the common culling age (Arbuckle *et al*. 2009). In sum, animal husbandry at Çatalhöyük included management of sheep (and goats) for meat and herd reproduction. The results of stable isotope analysis of human and faunal remains indicate that

sheep were the main source of animal protein (Richards and Pearson 2005); based on the evidence from milk residues it appears that the use of milk was of minor importance (Evershed *et al*. 2008).

The study of body part representation shows that, in general, sheep slaughter and butchery took place on-site (Russell and Martin 2005). Primary analysis of the faunal remains also suggests that *live* animals were present and kept at the site; finds of foetal/neonate bones and shed deciduous sheep teeth indicate some on-site birthing and tending of juveniles up to two years of age (Russell and Martin 2005). Furthermore, micromorphological evidence of compacted herbivore dung and laminated 'penning' deposits supports the argument for keeping animals in the settlement for an extended time (Matthews 2005a). The penned sheep/goat would have probably included birthing females (or those intended for milk supply) and some juveniles; articulated foetal/neonate bones sometimes found in penning deposits suggest natural deaths or deliberate killing of lambs possibly to free up the milk supply for humans (Russell and Martin 2005).

Penning areas identified by soil micromorphology constitute a very small part of the site and it is likely that only selected animals were kept there - some older (breeding and/or awaiting cull) sheep/goat and birthing females - while the rest of the flock could have been herded and managed off-site (Russell and Martin 2005). Penned livestock would have required some labour input in terms of fodder provision in seasons when pasture was not available, or suitable graze in close proximity to the settlement, in which case the sheep/goat may have been penned on-site overnight; the diet may have been supplemented by arable by-products. Confined animals would have provided readily available dung for use as fuel (see Section 7.3.5 below).

Analysis of oxygen stable isotopes and dental microwear in sheep tooth enamel has provided additional data on Çatalhöyük sheep herding practices (Henton 2010, 2012, in press/2013). These results are particularly relevant for assessing seasonal availability and location of animal food resources. Sequential sampling of sheep molar teeth for oxygen stable isotope analysis – relevant to birth and the first year of life – suggests that the lamb birthing season peaked in late spring (May) and that the majority of lambs in the first year of life were reared in low-lying zones of the Konya plain and maybe at slightly higher elevations (sand ridges and terraces), but not in the distant high mountain zone. A minor proportion of animals

display signatures consistent with higher-altitude grazing habitats as (summer) transhumance or with pasturing near springs with averaged groundwater such as Pinarbaşı near Karadağ (Henton in press/2013). The evidence suggests that sheep grazing could have taken place in the area close to the settlement, from at least late spring onwards; it follows that sufficient pasture was available near the settlement throughout the warm season for at least part of the flock, including birthing females and newborn and juvenile animals, and it is likely that they were (also) kept in the identified penning areas, as indeed evidenced by faunal data (see above). Springtime grazing of crop fields could have been practised as it promotes tillering (Ellenberg 1988; Bogaard 2004a; Halstead 2006), while non-arable grazing would be particularly critical during the seed-production phase in crops, when fields need to be protected from trampling animals.

The sheep dental microwear evidence (which relates to the final days before death) points to two possible culling seasons - early summer for sheep fattened on spring pastures, and winter for sheep fattened on summer-autumn pasture and cereal stubble-graze. The proposed 'fattening period' largely overlaps with the lamb birthing season and the early period (i.e. first year) of their life. If the sheep intended for slaughter were kept within or near the settlement, then it appears that, as well as for juveniles, suitable highly-nutritious ('dedicated') pastures were available nearby for other parts of the flock/flocks from spring onwards (Henton 2010, in press/2013), though in theory grazing could have been supplemented by crop processing waste (and/or crop products) or hay stored as winter fodder.

The analysis of sheep dental microwear evidence further indicates an array of nutritious graze available and accessible to sheep before slaughter. The majority of the analysed specimens from the chronological sequence included in this study belong to sheep that had fibre-rich diets based on grass, reed or sedge, and including hay or cereal fodder and cereal stubble. A smaller number of specimens seem to have fed on soft foods such as field weeds, tree leaves and legume straw (Henton 2012, in press/2013). The impression of highly diverse livestock diet is supported by a broad range of sheep/goat stable carbon and nitrogen isotope values for most of the period, which suggest general reliance on C3 plants but also consumption of C4 plants, both groups recognised in the previously analysed macrobotanical assemblage (Richards *et al*. 2003; Fairbairn *et al*. 2005a; Pearson *et al*. 2007). A possible change from a more or less homogeneous caprine diet (with significant/dominant contribution of C4 plants) characteristic of Pre-Level XII.D-C/South G to a more diverse one (based on the wider

isotopic variability) from Pre-Level XII.B/South G onwards has been observed, and interpreted as a possible transition from small-scale, local herding to larger-scale practices involving the keeping of separate flocks in different, perhaps distant, environmental zones (Pearson *et al*. 2007). This would have accorded with the exploitation of a range of ecozones, and the suggested long-distance agriculture implied by the previous palaeoenvironmental model (Fairbairn *et al*. 2005; Rosen and Roberts 2005; Roberts and Rosen 2009). However, the herding location for first year-sheep, inferred from the results of oxygen stable isotopes analysis, would have been confined to nearby low-lying areas throughout the early-mid Neolithic occupation; the possibility of transhumance and a change in diet was noted for later (i.e. late Neolithic) phases (Henton 2012: 3271, Fig. 13). The sheep dental microwear signature for the whole of early-mid Çatalhöyük East occupation indicates dryland vegetation food sources such as fibrous grasses and cereal stubble but also 'soft' foods such as legume straw and field weeds, as well as wetland edge vegetation - grasses, sedges and reeds (Henton 2012: 3271, Fig. 14; in press/2013). Based on the consistent and frequent presence in the deposits of a range of taxa from all of these habitats (Fairbairn *et al*. 2005a; Rosen 2005; Matthews 2005a), they would have probably been available in areas adjacent to the site.

In conclusion, and mostly based on the results of oxygen stable isotope and dental microwear analysis for the studied occupation sequence, it is likely that Çatalhöyük sheep were reared in close proximity to the site, where grazing on vegetation consisting of grasses, reeds, rushes and sedges would have been viable from early spring long into the winter season, supplemented by field-edge weeds and cereal stubble, without major long distance movement of herds or ample use of fodder (Henton 2012, in press/2013). The role of C3 and C4 plants in animal diet through time is explored below (Section 7.2.2.2).

7.2.2 **Evidence of sheep diet from the present study**

Selected ecological and biological characteristics of the dung-derived botanical taxa are given in Table 7.2 forming a basis for consideration of different aspects of sheep/(goat) diet, such as seasonality and method of consumption, and diversity of the resourced vegetation.

			Fruiting months													
TAXA	**Plant stem height**	***Method of consumption***	April	May	June	July	August	September	October	November	***Timing of grazing and/or fodder collection***	**annual**	**biennial**	**perennial**	**Habitat**	**Photosynthetic pathway**
Helianthemum Adans.	up to 30 cm	*grazing*	y	y	y	**y**	y				*spring-summer*	x		x	Dry	C3
Ziziphora capitata L./*persica* Bunge	4-15/5-20	*grazing*		y	y	**y**	y				*spring-summer*	**x**			Dry	C3
Salsola L.	5-60 cm	*grazing*			y	**y**					*(early) summer*	x		(x)	Wet	C3/C4
Heliotropium L.	up to 40 cm	*grazing*			y	**y**	y				*summer*	**x**			Dry	C3/C4
Aeluropus Trin.	9-25 cm	*grazing*			y	**y**	y	y	y		*summer-autumn*			x	Wet	**C4**
Sporobolus R. Br.	up to 40 cm	*grazing*		y	y	**y**	y	y	y		*spring-autumn*			x	Wet	**C4**
Carex L.	5-130 cm	*grazing/collection*												x	Dry/wet	C3
Bolboschoenus glaucus (Lam.) S.G. Smith	100-200 cm	*grazing/collection*	y	y	y	**y**	y				*spring-summer*			x	Wet	C3
Leguminosae , small wild	up to 250 cm	*grazing/collection*		y	y	**y**	y	y			*spring-summer*	x	x	x	Dry	C3
Beta L.					y	**y**					*(early) summer*	x	x	x	Dry	C3
Chenopodium L.	5-150 cm	*grazing/collection*			y	**y**	y				*stubble grazing*	**x**			Dry	C3
Polygonum aviculare aggregate						**y**	y	y	y	y	*stubble grazing*	**x**			Dry	C3
Artemisia annua L. type	up to 250 cm	*grazing/collection*				**y**	y	y			*late summer*	x	x	x	Dry	C3
Eragrostis N.M. Wolf	up to 125 cm	*grazing/collection*			y	**y**	y	y	y	y	*summer-autumn*	x		x	Dry/wet	**C4**
Juncus L.	5-150 cm	*grazing/collection*	y	y	y	**y**	y	y			*spring-autumn*	x		x	Wet	C3

Table 7.2 Selected ecological and biological characteristics of the dung-derived plant taxa

7.2.2.1 **Method and season of plant consumption**

The timing (season), method (foraging and/or fodder collection) and choice of plants consumed by sheep may have been influenced by differential palatability of plants or plant parts in different growing stages, the seasonality of (maximum) availability of leaves and stems, and accessibility - e.g. plants growing in open spaces versus those growing within thickets of spiny vegetation (Garner 1963; van Soest 1987; Hussain and Durrani 2009). The taxa identified as dung-derived are all palatable (with the possible exception of some spiny small-seeded legumes from the genus *Astragalus*, and a few toxic *Carex* species) and relatively easily accessible: they prefer open, well-lit spaces (see below). Moreover, some taxa (e.g. *Juncus*) disperse their seeds via animal ingestion (endozoochory) and 'attract' animals with, for example, evergreen foliage (*Juncus*), aroma (*Artemisia*) or colourful inflorescence (*Helianthemum*).

Some aspects of morphology of the dung taxa may shed light on the ways in which they were exploited. For example, plant (stem) height and structure can be used to assess likelihood of foraging and/or fodder collection. Table 7.2 shows the resulting grouping of taxa into grazed and grazed/collected, according to their stem height.

Several taxa (7) can potentially grow tall (up to 150 cm or 250 cm), depending on the growing conditions and locally competing vegetation. These taxa could have been grazed, but could also have been cut and collected for hay; however, plants intended for hay are usually harvested at the time when the leaf is at its maximum, up to the time when plants are in full flower, i.e. before the seed is ripe (as plants mature, proportion of leaves and hence palatability decreases - van Soest 1987). For example, many grasses, rushes and sedges (e.g. *Juncus*, *Carex*) are too hard or not quite palatable when in seed-bearing phase of life (Ellenberg 1988: 21) and would probably not be collected as (first-choice) fodder. Grazing animals, however, may need to consume whatever they find in the landscape if/when alternative vegetation is not available. Another group of taxa (6) are low-growing, up to 40-60 cm high; some are decumbent, such as *Salsola*, or with creeping stolons, such as *Aeluropus*; most of them have a short and dense inflorescence, with seeds positioned close to the leaves. These dense and low-growing taxa are pre-adapted to grazing (especially by sheep - Garner 1963), which permits plant regeneration, while seeds can germinate after passing through the

animal gut (Gardener *et al*. 1993). It is likely that both 'tall' and 'short' taxa were consumed by sheep *in situ*.

Given that the dung-derived taxa are all represented as seeds in the archaeobotanical samples, their estimated fruiting time (see Section 5.4.2.2) offers a basis for determining the time of the year when they were grazed by sheep. As shown in Table 7.2, six taxa start producing seed in spring (April, May), while seven taxa can produce seed well into autumn (up to and including November). Nearly all taxa are in seed for most of the summer (June-August), and indeed all of them in July. This means that the dung-derived taxa could reflect sheep grazing over a continuous period from mid-spring to autumn (a 'maximum' grazing period), or a period as short as the single month of July (a 'minimum' grazing period). The potentially long grazing period is also indicated by the results of oxygen stable isotope analysis (Henton 2010, 2012, in press/2013). It could be argued that sheep (and goat) droppings have been readily obtainable for collection as fuel, implying that the grazed vegetation was available relatively close to the settlement, and that the animals were present in some numbers around the site for at least the 'minimum' grazing period (see below).

As shown by primary analysis of faunal remains, oxygen stable isotopes and dental microwear - some, if not all, sheep/(goat) were herded relatively close to the settlement at least for part of the year. Although dominated by hulled wheat, the three penning deposits analysed here all contained charred seeds of some dung-derived taxa, mainly *Bolboschoenus* and small-seeded legumes, and some *Sporobolus*. However, no *in situ* burning in penning areas was recorded, meaning that the charred remains come from a different context and do not represent primary deposits. Mineralised seeds found in the penning layers, on the other hand, probably derive from *in situ* deposited sheep pellets; a single sample from penning in Space 199 provided a small number of mineralised *Bolboschoenus* seeds. Fairbairn *et al*. (2005a) also recorded the presence of mineralised seeds of small-seeded legumes *Astragalus/Trigonella* and *Bolboschoenus* in penning contexts from Space 199 and Space 198. These mineralised penning assemblages could point to foddering of penned animals over winter, and/or spring-autumn grazing and keeping of animals in pens over night.

7.2.2.2 **Life-cycle and habitat**

Plants with annual and short- and long-perennial life-cycles are represented in the dung-derived assemblage; this may be in some instances indicative of their varying growing conditions (Grime 2002). For example, from the aspect of damage upon biomass (caused by a range of mechanisms – from natural to human-induced), annual and short-lived perennial (biennial) taxa are potentially adapted to persistent and severe soil disturbance, such as that of cultivated land. Long-lived perennials on the other hand, form a very diverse group of woody and herbaceous plants growing in undisturbed (natural, e.g. forests) to moderately disturbed habitats (such as those in abandoned arable fields and pastures), while some possess regenerative strategies enabling them to successfully thrive in less favourable environment, e.g. in highly disturbed soil conditions (Grime 2002).

Among the dung taxa, four are exclusive annuals (Table 7.2); of those, *Polygonum* and *Chenopodium* are ruderals specifically adapted to repeated disturbance (though ruderal plants are short-lived even in the absence of disturbance - Grime 2002: 85) and they represent typical cereal stubble weeds. Six taxa belong to annual/perennial or perennial grasses and other monocotyledons (rushes and sedges) that tend to develop an extensive horizontal system of rhizomes or stolons, enabling some of them (i.e. *Bolboschoenus*, *Carex*, *Aeluropus* and *Sporobolus* – J. Hodgson, pers. comm.) to regenerate from fragments (regeneration by vegetative expansion – Grime 2002). Vegetative expansion (patch-forming, root-sprouting) in some stoloniferous (especially short-lived) grasses is a response to, and a way of overcoming intensive disturbance, whereas other grasses and forbs can be very sensitive to high level of soil disturbance, such as in arable fields (Lavorel *et al*. 2007; Martínková *et al*. 2011). It appears that the dung taxa likely grew in a range of habitats, from natural/undisturbed to moderately, to extremely disturbed places.

On the basis of broad habitat categories (Section 5.4.2.1), three groups of taxa can be distinguished (Table 7.2). The information available in *Flora of Turkey* (Davis *et al*. 1965-1988; Güner *et al*. 2001) shows that the majority of dryland (and the two dryland/wetland taxa - 'intermediate' taxa) can be found in natural/undisturbed habitats – stony slopes, rocky outcrops, gravel terraces (e.g. *Heliotropium, Helianthemum, Ziziphora capitata* L., some small-seeded legumes such as *Astragalus*), or more 'open' places – steppe, grassland, sandy banks (e.g. *Artemisia, Ziziphora persica* Bunge, some *Helianthemum* and *Heliotropium*

species), while, with the exception of *Helianthemum*, they can also grow in 'disturbed' areas - in and around cultivated (and fallow) fields, on settlement edges and along pathways, in ditches, trampled areas and waste places. The two intermediate taxa (*Carex* and *Eragrostis*) can also thrive in damp or wet areas, both freshwater (river and lake banks) and salty environments (salt marshes).

The five wetland taxa represent the other end of the habitat spectrum, and are generally associated with natural/undisturbed places. The most frequent and abundant dung-derived taxon in the assemblage (Ch. 4), *Bolboschoenus glaucus*, is a freshwater species and frequently grows along rivers and streams, in field depressions and shallow pools (Hroudová *et al*. 2007: 44). It can form dense stands under favourable conditions (with sufficient water supply), but is also well-adapted to summer-dry habitats and high temperatures (Hroudová *et al*. 2007: 44). Similar to *Carex* and *Eragrostis*, two of the wetland taxa – *Juncus* and *Aeluropus* - thrive in both freshwater and saline environments, which are wet temporarily or year-round (e.g. marshes drying out in summer, salt encrusted grassland, abandoned cultivated fields). *Salsola* and *Sporobolus* are halophytes - they can complete their lifecycles in habitats with moderate to high concentrations of salts in the soil, for example in salt steppes of low-lying areas surrounding salt lakes or in saline and brackish marshes.

In terms of adaptability to growing conditions reflected in the type of photosynthetic pathway, all dryland and intermediate taxa except *Eragrostis* are C3 plants; *Heliotropium* can also develop C4 metabolism. In contrast, most of the wetland taxa are C4 plants, exceptions being *Bolboschoenus* and *Juncus*, while *Salsola* varies between C3 and C4 pathway. In general, C4 plants are more successful under arid conditions (drought, high temperatures) and nitrogen limitations compared to C3 plants, while C3 plants prefer less arid environments (Ehleringer and Monson 1993; Richards and Pearson 2005). In studies of ecological aspects of photosynthetic pathway variation, a correlation between temperature and precipitation has been observed; C4 plants seem to have a greater growth potential in dry and warm seasons/areas due to their the high(er) water-use efficiency (which could in fact be a result of higher water demand in the preferred warm environment – Wickens 1998: 138), while C3 plants predominate at the wetter/cooler extreme of the environmental gradient (Ehleringer and Monson 1993). Based on this characteristic of C4 plants, they would have potentially been abundant around Çatalhöyük if summers of the Konya plain were as dry and hot in the Neolithic as they are today. However, the results of palaeoclimatic research show that the

climate of Central Anatolia during the Early Holocene was wetter, as was the then seasonally flooded landscape (Section 2.3.2). Indeed, a majority of the dung-derived C4 taxa are associated with damp to wet habitats (Table 7.2), while most dung-derived C3 plants actually thrive in dry places. Furthermore, the dung-derived C4 taxa are adapted to saline conditions, two of them growing exclusively in salty places. Water-use efficiency appears to be an important factor for survival of plants in saline environments; as the salt content tends to increase over time in soils of wet low-lying areas, C4 plants replace C3 plants on more saline sites (Ehleringer and Monson 1993). A few of the 'non-dung' and infrequent taxa can also grow in salty places (some *Atriplex* species, *C. chenopodioides*, *Suaeda*, *Crypsis*) and they use C4 (*Crypsis*) or C3/C4 photosynthetic mechanism. The C4 plants analysed within this study are perhaps specifically associated with wet saline (warm) growing conditions, which probably existed close to the settlement (Roberts and Rosen 2009).

As mentioned above, the relatively narrow range of carbon and nitrogen isotope values detected in sheep/goat bone from the site's first occupation phases (Pre-Level XII.D-C/South G, *c*. 7400-7080 cal BC - Cessford 2001), including a significant dietary contribution of C4 plants (suggested by $\delta^{13}C$ values >-18‰) has been understood as indicating exploitation of a small, environmentally uniform, geographic zone, probably in the site's vicinity (Pearson *et al*. 2007). The stable isotope figures for the period from Pre-Level XII.B/South G through to Level VII/South M suggest a more varied diet and herding of sheep/goat over a wider, more environmentally diverse area (Pearson *et al*. 2007).

Previous archaeobotanical work identified several C4 and C3/C4 taxa (e.g. *Aeluropus*, *Atriplex*, *Salsola*) which were present in majority of the sampled phases (Fairbairn *et al*. 2005a: Table 8.2). In the present study, both C3 and C4 dung-derived taxa are regularly found throughout the chronological sequence covered (see Table 4.8). Figure 7.1 shows the distribution of C3 and C4 dung-derived taxa across the assemblage and the excavation areas (compare with Figs. 6.42-6.50). The lower end of the plot corresponds with the early occupation phases in the South Area (see Fig. 6.50), including the sample from Pre-Level XII.B (Fl. 3324) positioned at the lower left end of the plot and rich in the C4 taxon *Aeluropus*, and the sample at the lower right end of the plot deriving from Pre-Level XII.C (Fl. 3742) and associated with C3 taxa *Juncus* and *Artemisia*. Figure 7.2 shows proportions of C3 and C4 dung-derived taxa (and C4 non-dung taxa) in the assemblage. It appears that both C3 and C4 plants were consumed continuously over the period studied, and perhaps in similar

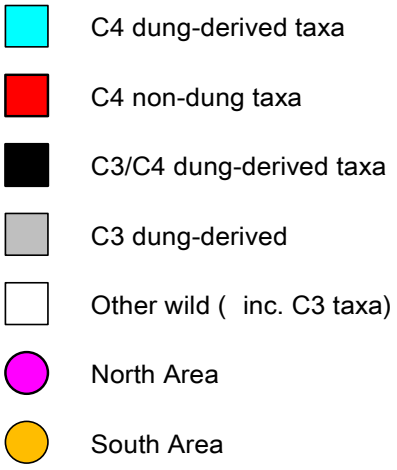
proportions, with an overall greater contribution from C3 plants. The archaeobotanical analysis of the mid-late Neolithic occupation has also revealed a similar suite of C4 dung-derived taxa (Bogaard *et al*. in press/2013). The implication is that both dryland and wetland habitats were present and grazed by sheep throughout the life of the settlement. The occurrence of typical cereal stubble weeds in the dung assemblage, and the possible dung-origin of some 'non-dung'/arable weed taxa (e.g. the non-dung C4 plants) may reflect a practice of sheep herding across wetland and arable habitats, which could explain the varying isotopic values. No clear indication of the shift in sheep/goat diet (and potential change in herding practices) detected in the sheep isotope record after the earliest occupation phases is apparent in the dataset analysed.

7.2.3 **Conclusions**

The dung indicators identified within this study originate from sheep/goat pellets and provide direct evidence of livestock diet. Due to the evident dominance of sheep in the faunal assemblage, the relevant information from multiple sources on sheep husbandry was used as a background to the discussion on aspects of animal plant consumption.

Based on the relevant biological characteristics of the dung taxa, combined with the results of sheep dental microwear analysis, it seems that grazing was the general method of consumption and that it could have been practised from mid-spring until late autumn. It has previously been suggested that, during the assumed two-month spring flood period (March-April), most of the landscape surrounding Çatalhöyük would have been inundated and the settlement mound made virtually an island, implying that sheep/goat grazing and browsing over this period would have not been viable due to the inaccessibility of vegetation, "and neither animal adapt easily to having wet feet" (Roberts and Rosen 2009: 396). Based on the archaeobotanical evidence, however, local spring grazing cannot be excluded. Moreover, the oxygen isotope data show that sheep were mainly herded in a low-altitude zone within the Çarşamba fan, not far from the settlement (Henton 2010, 2012, in press/2013), and were fed on local food resources which seem to have been available and sufficient for both lambs and adult sheep. The dung-derived taxa identified are all palatable and would offer a variety of choice and high nutritional levels in animal diet.

Figure 7.1
Correspondence analysis combined plot showing distribution of C3 and C4 taxa and the samples deriving from different excavation areas (75 samples and 52 wild taxa included, see Section 6.2)



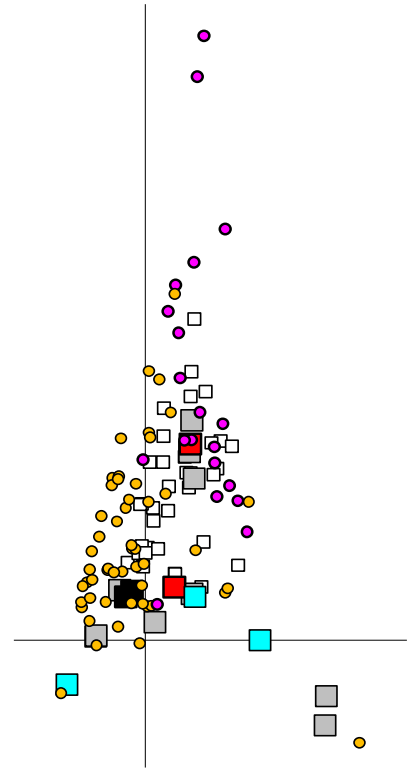
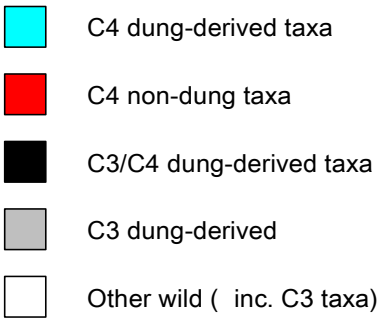
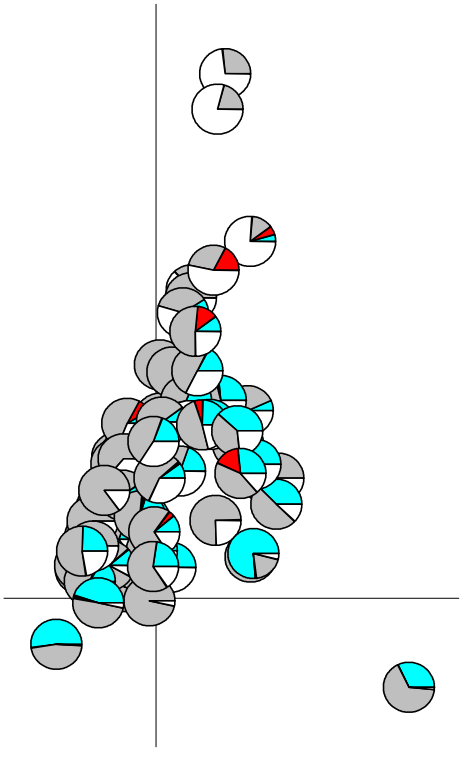


Figure 7.2
Correspondence analysis plot showing relative proportions of C3 and C4 taxa (75 samples and 52 wild taxa included, see Section 6.2)





Figures 7.1-7.2 Axes	**1**	**2**	**3**	**4**	Total inertia
Eigenvalues	0.703	0.374	0.283	0.175	2.96
Cumulative percentage variance of species data	23.8	36.4	45.9	51.8	

Consideration of the habitats of the dung-derived taxa reveals that they originate from a wide range of natural (dry and wet) and human-influenced areas, which would have been distributed in the site's vicinity, reflecting a diversity and complexity of the surrounding landscape; for example, the co-occurrence of dry/ruderal/C3 taxa (of which some specifically characteristic of field-edge/cereal stubble) and wet/saline/C4 taxa in the dung-derived assemblage may indicate proximity of different (interspersed) vegetation zones accessible to grazing sheep.

Combined faunal evidence, soil micromorphology and archaeobotanical data demonstrate that at least some sheep/(goat) were penned within the settlement. In addition to the pasture, (penned) animals could have been fed some crop processing by-products/products and other fodder, especially in winter, though no definite archaeobotanical evidence of foddering has been discovered (e.g. in store). Penning areas could have been the (main) source of dung used as fuel (see Section 7.3.5).

7.3 Crop husbandry

The study of crop husbandry can reveal details on agricultural management of the available resources (i.e. arable land, farming skills, and technological solutions) aimed at meeting the demands of a farming society. Farming methods are determined by the choice of crops, the environmental context, field techniques, level and scheduling of crop food production, and labour force availability. Understanding of farming methods can shed light on these and other aspects of life in the past, including settlement location and pattern, socio-economic organisation, animal husbandry and environmental conditions.

Based on the previous Çatalhöyük archaeobotanical work (Fairbairn *et al*. 2002, 2005a) and the palaeoenvironmental evidence (Roberts *et al*. 1999, 2001; Roberts and Rosen 2005) it has been argued that the agricultural system at the site combined extensive and intensive strategies, and that the size and location of crop fields changed over time, depending on the availability of cultivable land and demands for food by the growing population (Fairbairn 2005). According to this view, an extensive low-labour input system was applied on widely dispersed and distant dry soils, whereas fields close to the site (i.e. within a 5 km radius – Fairbairn *et al*. 2002) were under more intensive exploitation, especially during the main

occupation phase when the population was at its peak (Fairbairn 2005; see Cessford 2001, 2005 for site chronology and population). In terms of sowing time, the presence of character species of the Secalinetea phytosociological class in the analysed crop stores were seen as indicators of autumn sowing, whereas the occasional finds of Chenopodietea species were understood as reflecting possible spring sowing and/or intensive cultivation practices (Fairbairn *et al*. 2005a, Fairbairn 2005). Also, based on the weed record, general cropping of dry land was suggested, though the presence of wetland taxa indicated some agricultural activity in wetter areas (Fairbairn 2005).

As noted by Fairbairn *et al*. (2002, 2005a) and Fairbairn (2005), the reconstruction of crop growing conditions and husbandry practices at Çatalhöyük based on the results of previous archaeobotanical analysis was largely constrained by the fact that plant remains deriving from dung used as fuel were inseparable from those representing crop processing residues. The arable weed assemblage identified within the present study offers a unique opportunity for investigation of cultivation practices in early-mid occupation phases at Çatalhöyük. The following sections present results of a detailed consideration of selected ecological and biological characteristics of the identified weed taxa relevant to the main aspects of agricultural activity at Çatalhöyük, such as the permanence of crop fields, sowing time, and the labour-intensity (and scale) of crop cultivation.

7.3.1 Approaches to the study of crop production based on archaeobotanical weed evidence

Archaeobotanical data can provide direct evidence of past crop husbandry. In particular, weed assemblages from archaeological sites have the potential for identification of specific farming practices, as their ecological preferences reflect the growing conditions of associated crops (e.g. Dennell 1976; Hillman 1981, 1984a; Wasylikowa 1981; Jones 1984, 1987, 1992, 2000; van der Veen 1992; Hoppe 1999; Bogaard *et al*. 1999, 2001; Charles *et al*. 1997; Bogaard 2002, 2004a; Valamoti 2004; Hald 2008). Some inferences about crop husbandry practices can be made from the presence and composition of crop types; crop species, however, can thrive in a range of growing conditions (e.g. populations of emmer adapted to dry and wet conditions – Davies and Hillman 1988) and may be relatively tolerant of changes in humidity, salinity etc; hence crop species *per se* do not offer an adequate basis for the reconstruction.

Arable weed flora accompanying crops are highly sensitive to changes in the growing environment. Different farming practices modify the arable habitats in different ways, significantly affecting the ecological composition of weed assemblages. In response to variable conditions of arable environment the composition of weed assemblages, represented as seeds associated with crop remains, varies through space and time. The arable weed record is, therefore, an extremely useful indicator of crop growing conditions and farming practices such as tillage, weeding, irrigation/drainage, fertilisation, fallowing/crop rotation cycles. Furthermore, it can reveal sowing and harvesting time and methods, the intensity and scale of cultivation, location (and size) of arable fields and their productivity, and the scheduling of agricultural tasks (Hillman 1981; Wasylikowa 1981; Behre and Jacomet 1991; van der Veen 1992; Jones 1984, 1987, 1992, 2000; Charles *et al*. 1997; Bogaard *et al*. 2000, 2005b; Bogaard 2002, 2004a).

There have been different analytical methods used in the study of ecology of arable weeds as potential indicators of past husbandry regimes, for which modern studies have provided a crucial source of comparative data (e.g. Jones 1992, 2002; Jones *et al*. 1999, 2000a; Charles *et al*. 1997; Bogaard *et al*. 1999, 2001; Bogaard 2004a: 5-9). The phytosociological approach is frequently used (e.g. Knörzer 1971; Wasylikowa 1981; M. Jones 1988; Jones 1992); this method is based on field observations of diagnostic taxa ('character species') restricted to specific communities ('associations'), or broader groupings (up to the most general level of 'class'). Wild plant communities are generally more habitat-specific than crops, and information on their ecology can be used to infer crop growing conditions and cultivation practices. Similarly, in archaeobotanical weed assemblages the presence of certain character species can reflect the occurrence of specific plant communities in ancient arable fields, offering information on the growing environment. As in all weed-based approaches, it is assumed that the present-day ecology of weed species does not significantly differ from that of the past, which may not be entirely the case; however, the reliance on the *suites* of taxa (rather than on individual character species) makes uniformitarian assumptions more plausible, since any changes in preferences of individual species within a group would not all be towards a same new trend (Jones 1992).

Among plant communities, the low-level ones (e.g. associations) are of limited usefulness for archaeobotany since the conditions they occur in may be very restricted in time as well as space; they tend to have very specific ecological requirements, usually relevant for distinct

geographic areas (Holzner 1978; Jones 1992). Compared to more general groupings, lower syntaxa are affected to a greater extent by changes in, for example, edaphic conditions and cultivation techniques, and so their floristic composition can change through time (Wasylikowa 1981). Higher syntaxa (i.e. alliances, orders, classes) on the other hand, are less specific indicators of habitat conditions but are representative of a larger territory and of a longer period of time (their floristic composition is fairly stable). Therefore, higher-level phytosociological units (i.e. alliances, orders, classes) are more reliable in reconstructions of ecological conditions in arable environment since they remain generally unchanged through time and are valid over a larger territory (Behre and Jacomet 1991; Küster 1991; Jones 1992, 2002).

Character species of two phytosociological classes - Secalinetea and Chenopodietea - have often been used in studies of modern and archaeobotanical weed assemblages; the two classes encompass the arable weeds and ruderal flora of central Europe and the Mediterranean (Holzner 1978; Ellenberg 1950, 1988; Jones 1992). For example, from present-day phytosociological observations it has been understood that Secalinetea character species (and communities within the class) occur mostly in autumn-sown fields (and are autumn-germinating), whereas Chenopodietea character species and their companions are common in spring-sown crops (and are spring-germinating) (Knörzer 1971; Behre and Jacomet 1991; Jones 1992). Based on this, it would follow that the presence/dominance of Secalinetea character species in archaeobotanical samples indicates autumn sowing, and presence/dominance of Chenopodietea character species points to spring-sown fields. Nowadays, cereals are almost always grown in fields and most are sown in autumn (summer cereals are for example oats, millets); Secalinetea associations are associated with winter cereals and usually represent winter annual weeds. Chenopodietea are characteristic of summer crops and are mostly summer annual weeds, while they also occur in gardens and root/row ('tilled') crops (Ellenberg 1988; Jones 1992; Jones *et al*. 2000a).

However, not all Chenopodietea character species are spring-germinating, and some character species of both classes can germinate in autumn *and* spring (Ellenberg 1988). Furthermore, Chenopodietea character species also grow in gardens, with root or row crops (as opposed to 'straw' crops characterised by Secalinetea) and in ruderal areas (Ellenberg 1988). Gardens and root/row crops are subject to intensive farming (tillage, weeding, heavy fertilisation and watering - Ellenberg 1988); the presence of Chenopodietea in archaeobotanical samples could

therefore reflect different cultivation methods or contamination by vegetation of waste ground (ruderals) rather than sowing time (Wasylikowa 1980; M. Jones 1988; Jones 1992). Jones *et al*. (1999) conducted a modern study on the Greek island of Evvia and compared the weed flora of autumn-sown pulses intensively cultivated in small garden plots within villages, and the same pulses sown in autumn in less intensively cultivated (in terms of tillage, weeding, watering, fertilising) larger fields situated at some distance from the villages. The intensively cultivated plots contained an abundance of Chenopoidetea character species, while weeds of less intensively cultivated plots comprised mainly of members of the Secalinetea class (Jones 1992; Jones *et al*. 1999).

Combinations of Chenopodietea and Secalinetea character species and their companions are relatively common in archaeobotanical assemblages (e.g. Wasylikowa 1981; Jones 1992; Behre and Jacomet 1991). Furthermore, in past weed floras character species of Chenopodietea are often more abundant than Secalinetea, which raises the possibility that ancient agriculture involved intensive cultivation of both root/row and grain crops (cereals) (Halstead 1989). The abundance of character species of one or the other phytosociological class in weed assemblages could then reflect differences in cultivation regimes between small-scale intensively cultivated gardens characterised by Chenopodietea, and larger fields receiving less frequent cultivation and rich in Secalinetea (Jones *et al*. 1999). Therefore, as well as the differences in sowing time, contrasting intensities and scales of cultivation (and probably other potential causes, such as ruderal contamination) can affect the floristic composition of weed flora.

The phytosociological method of determining sowing time (and other aspects of past cultivation regimes) has some obvious drawbacks in application to archaeobotanical assemblages. In addition to the ambiguous linkage of Secalinetea and Chenopodietea characters species (and associated plant groups) with winter- or spring-sown crops, respectively, present-day weed communities may not correspond well with the past syntaxa due to possible changes in ecological preferences and properties of individual species, meaning that plant associations may not remain stable and retain their composition through time (some species may have grown in different geographic areas - Holzner 1978) and some may have become extinct (Knörzer 1971; Hillman 1991; Jones 1992, 2002; Charles *et al*. 1997; Bogaard *et al*. 2001; Bogaard 2004a). On the other hand, material in archaeobotanical samples may not derive solely from arable field(s) and likely not from a single field;

contamination by ruderal vegetation is sometimes possible. Furthermore, archaeobotanical samples cannot be understood as a record of all weeds present in a field, as the employed harvesting method may introduce a bias towards e.g. taller weeds (Knörzer 1971), which can also be avoided if taller than crops; some weeds shed seed well before harvest or set seed after harvest and do not accompany the grain (Jones 1984, 1992, 2002).

In conclusion, plants respond to multiple environmental factors, such as climate (precipitation, temperature), soil properties, seasonal changes and altitude (Hüppe and Hofmeister 1990; Bogaard *et al*. 2001; Lososova *et al*. 2004); in addition, arable weeds are sensitive to different cultivation practices (time of sowing crops, measures applied to improve yields etc). Knowledge of the ecological properties of present-day weed communities does not reveal which of the aspects of arable habitats affected the ecological composition of archaeobotanical weed assemblages. In order to determine which husbandry practice is responsible for the presence of weed species with specific ecological characteristics, it is necessary to explore how these species react/adapt to variable conditions of arable environment (Charles *et al*. 1997; Jones *et al*. 2002; Bogaard 2004a).

Instead of inferring past farming regimes by looking at the floristic composition of archaeobotanical weed assemblages, a functional ecological approach to species' ecology has been developed to investigate the impact of ecological variables on plant composition - Functional Interpretation of Botanical Surveys (FIBS) (Charles *et al*. 1997; Jones 2002; Jones *et al*. 2010). This method measures adaptive (i.e. morphological and behavioural) characteristics - 'functional attributes' – which reflect species' potential response to major ecological variables such as fertility, soil disturbance and moisture; it provides a link between individual plant species and their growing conditions. Measurements of functional attributes have been collected for a number of modern weed species and assigned to ecological factors in known husbandry regimes (Charles *et al*. 1997, 2002, 2003; Bogaard *et al*. 1999, 2001; Bogaard 2004a; Jones *et al.* 2000a). Based on the measured functional attributes it has been possible to identify ecological factors relevant to present-day 'traditional' crop husbandry practices, and to identify causes for the co-occurrence of species in certain locations; the method has also enabled comparison of different datasets and studies (i.e. different husbandry regimes, modern and ancient) based on species' *characteristics* rather than on species themselves (unlike phytosociology), opening up the potential for comparisons between modern and archaeobotanical weed flora (Bogaard 2004a; Jones *et al*. 2010).

In this study, relevant biological and ecological characteristics of the identified arable weed taxa from Çatalhöyük available from *Flora of Turkey* (Davis 1965-1988; Güner *et al*. 2001) were used, as well as comparable results of modern weed surveys (e.g. Jones *et al*. 1999, 2000a; Bogaard 2002, 2004a), and FIBS was applied in the analysis of the cultivation intensity (Jones *et al*. 1999; Bogaard *et al*. 2000).

7.3.2 **The permanence of fields**

General habitat and life-history information can be used to determine whether the preparation of land for planting crops involved clearing of new plots for short-term cultivation, as in a shifting regime, or use of permanent, long-established plots ('fixed-plot' cultivation). Shifting agriculture (also called slash-and-burn, swidden etc.) involves cutting down (woodland) vegetation and burning of the remaining foliage (where ashes provide nutrients to the soil) to create land to be used over a relatively short period for crop growing; while clearance itself is labour-intensive, subsequent management of plots involves minimal labour input (tillage, weeding etc). The relatively short period of cropping is followed by abandonment so that vegetation can regenerate, while plots are 'shifted' to new locations (Grigg 1974; Gregg 1988; Milisauskas and Kruk 1989; Rösch 1996; Bogaard 2002, 2004a). Shifting cultivation is particularly widespread in the tropics, e.g. south and east Asia, parts of Africa, and North America (e.g. Gregg 1988; Sodarak 1999).

Models of fixed-plot cultivation refer to permanent plots, used over a relatively long period of time (decades to hundreds of years) and usually with different crops rotated on them (Gregg 1988; Bogaard 2004a). Depending on the type of soil and the time available for replenishment of nutrients, some effort may be required to maintain soil fertility (Gregg 1988), or, as proposed for floodplain cultivation model, fertility may be maintained naturally through alluvial silt deposition (Sherratt 1980; Bogucki 1996, 1999). As Gregg (1988: 32) noted, permanent and shifting cultivation do not exclude each other and they could have been combined in some way as complementary subsistence strategies of an agricultural community.

In order to explore the permanence of arable fields, that is, to assess whether shifting or fixed-plot cultivation best characterises Çatalhöyük crop production, the arable dataset was compared with a modern weed assemblage from the Hambach Forest experiment conducted

in Germany and analysed by Bogaard (2002, 2004a). In this experiment, crop fields were located in areas newly cleared of long-lived oak-hornbeam (*Quercus-Carpinus*) woodland. Tillage prior to sowing and, later on, weeding of crops were generally not practised in the first year of the experiment; they were applied to some of the plots in subsequent years in an attempt to improve yields, while all plots were subject to soil disturbance measures in the last two years of the six-year long experiment. One of the plots was burned before sowing; by adding nutrients to the soil burning improved growth of crops but also weeds (Bogaard 2002).

Analysis of weed survey data from the experimental plots (weed surveys recorded just prior to harvest) revealed a dominance of perennial weeds, able to regenerate after clearance and burning, from seed or via vegetative spread from roots/rhizomes. In plots with low-level soil disturbance (i.e. tillage and weeding) the most common taxa were woodland perennials, while fields with higher level of soil disturbance were characterised by perennials of more disturbed habitats. Some annuals from the local woodland vegetation and from disturbed (anthropogenic) habitats were also detected in all fields, but at low levels (Bogaard 2002).

By contrast, weed assemblages of fixed/permanent crop fields are often dominated by annual weeds (Ellenberg 1988: 626; Grime 2002). It is, however, important to note that perennials need some time after land clearance and burning to regenerate and start reproduction, and so they may not be detectable as seeds within first harvest(s) from freshly cleared plots. Nonetheless, in the second and later cultivation season they would (re-)appear in the weed record of shifting cultivation plots (Bogaard 2002). This is important for comparisons of the Hambach Forest data (and weed survey data from similar experiments – see Bogaard 2004a: 88) with archaeobotanical weed assemblages, since the absence of (woodland) perennials from archaeobotanical record need not necessarily point to fixed-plot cultivation. On the other hand, if an archaeobotanical assemblage under study is reasonably large (and covering some chronological sequence, so as to expect evidence from a number of cultivation seasons/fields), indicators of shifting cultivation, if practised, should be identifiable in the form of perennial weeds (woodland perennials in particular). In fact, as mentioned above, even in conditions of (severe) soil disturbance, perennials (of more disturbed habitats) still dominated weed assemblages from the Hambach Forest fields.

Based on observations from the Hambach Forest experiment, it can be concluded that arable weed flora in shifting cultivation fields, recently cleared from natural (oak woodland)

vegetation and tended without any or with very light (hand) tillage and no weeding during crop growth, would be dominated by perennials of woodland habitats. Perennials and annuals from disturbed habitats, and annuals from natural (woodland) flora would be expected in small numbers. Recently cleared plots that were moderately to highly disturbed (machine-tilled, hand-weeded and hoed) would be characterised by perennials associated with disturbed habitats. Some woodland perennials could occur in these fields, as well as annuals.

While the climate (and vegetation) of the Hambach region near Cologne is distinctly different to that of Central Anatolia, broad implications from the German weed survey can be used as a framework for exploring the type of cultivation regime(s) at Çatalhöyük, particularly because at Çatalhöyük at least some crop fields have likely been located in areas covered in oak woodland (see below). Following the principle applied by Bogaard (2002, 2004a), the lifecycle and preferred habitat of the Çatalhöyük taxa identified to genus and/or species level and represented by charred seeds were examined. Dung-derived (Table 7.1) and collected taxa (fruit, nut and tuber taxa and *Descurainia sophia*) were excluded from consideration. Furthermore, five taxa from the 'possibly dung-derived' group (Table 7.1) were excluded because of their uncertain (unlikely) role as weeds. Two of them - *Crypsis aculeata* (C4 plant) and *Chenopodium chenopodioides* (C3 plant) - are annuals specifically associated with saline habitats (salt marshes and edges of salt lakes). The small-seeded grass *Crypsis* has been recognised in dung remains and dung-containing samples recovered from the mid-late sequence at Çatalhöyük (Bogaard, pers. comm.) and its dung origin in the samples analysed within this study is possible. *Chenopodium chenopodioides* also has small hard-coated seeds and could be dung-derived, similar to *Suaeda* (C3/C4 plant), another halophyte with small hard-coated seeds, which is only occasionally found on cultivated land. The two wetland taxa, *Alisma* and *Potamogeton* (thriving in freshwater lakes, rivers, ditches, marshes, wet soil), were excluded due to their unlikely arable status; they may also be relevant for the investigation of animal diet since, for example, their seeds could have been ingested by animals while drinking water from natural water reservoirs.

Life history and habitat information extracted from *Flora of Turkey* (Davis *et al*. 1965–1988) were examined for 43 taxa, including rare types occurring in less than 5% of the samples. The 43 potential arable taxa are classified based on their lifecycle and habitat into four groups: perennials of natural (woodland) habitats, perennials of disturbed habitats, annuals of disturbed habitats, and annuals/perennials from disturbed places. Table 7.3 lists the members

TAXA	LIFECYCLE/HABITAT CATEGORY	*number of possible species within the taxon*	Ubiquity		Abundance
			count	%	
Stipa L.	perennial - undisturbed (steppe)	*15*	1	1.06	20
cf. *Potentilla* L. type	perennial - undisturbed (woodland)	*53*	2	2.13	3
Ranunculus L.	perennial - undisturbed (woodland)	*78*	2	2.13	2
Polygonatum Miller	perennial - undisturbed (woodland)	*5*	1	1.06	9
Viola L.	perennial - undisturbed (woodland)	*21*	1	1.06	1
PERENNIAL - UNDISTURBED (WOODLAND)			**5**	**5.32**	**15**
Convolvulus arvensis L. type	perennial - disturbed	*6*	39	41.49	194
Sideritis L. type	perennial - disturbed	*43*	26	27.66	291
Rumex L.	perennial - disturbed	*5*	23	24.47	559
Hordeum spontaneum C. Koch type	perennial - disturbed	*7*	4	4.26	7
Teucrium L.	perennial - disturbed	*7*	4	4.26	21
Verbena officinalis L.	perennial - disturbed	*1*	2	2.13	8
cf. *Secale* sp.	perennial - disturbed	*5*	1	1.06	1
Linum L.	perennial - disturbed	*38*	1	1.06	13
PERENNIAL - DISTURBED			**59**	**62.77**	**1094**
Taeniatherum caput-medusae L.	annual	*1*	68	72.34	617
Vaccaria pyramidata Medik.	annual	*1*	29	30.85	89
Eremopyrum (Ledeb.) Jaub. & Spach	annual	*4*	23	24.47	43
Cornucopiae cucullatum L. type	annual	*1*	21	22.34	85
Atriplex L.	annual	*5*	20	21.28	168
Adonis annua/aestivalis L.	annual	*2*	13	13.83	32
Hordeum murinum L. type	annual	*7*	11	11.70	13
Conringia orientalis L.	annual	*1*	10	10.64	34
Boreava orientalis Jaub. & Spach	annual	*1*	8	8.51	20
Chenopodium album L. type	annual	*5*	8	8.51	69
Fumaria L.	annual	*15*	5	5.32	10
cf. *Lallemantia peltata* L.	annual	*1*	3	3.19	5
Anagallis L.	annual	*2*	2	2.13	7
Valerianella Miller	annual	*21*	2	2.13	3
ANNUALS			**83**	**88.30**	**1196**
Bromus danthoniae Trin. type	annual/perennial	*35*	34	36.17	80
Galium aparine L. type	annual/perennial	*112*	32	34.04	92
Silene sp.	annual/perennial	*>100*	20	21.28	214
Vicia L./*Lathyrus* L.	annual/perennial	*many*	18	19.15	31
Centaurea sp.	annual/perennial	*c. 200*	12	12.77	31
Lavatera L. type	annual/perennial	*6*	12	12.77	14
Thymelea passerina (L.) Cosson & Germ.	annual/perennial	*7*	9	9.57	27
Malva L.	annual/perennial	*9*	8	8.51	12
Androsace L.	annual/perennial	*7*	5	5.32	39
Polygonum convolvulus L.	annual/perennial	*1*	4	4.26	4
Galium verum L. type	annual/perennial	*112*	3	3.19	43
Erodium L'Hérit.	annual/perennial	*29*	2	2.13	2
Capsella Medik.	annual/(biennial)	*2*	1	1.06	1
Euphorbia L.	annual/perennial	*93*	1	1.06	2
Geranium L., small type	annual/perennial	*33*	1	1.06	1
Papaver L.	annual/perennial	*36*	1	1.06	2
ANNUAL/PERENNIAL			**70**	**74.47**	**601**

Table 7.3 Classification of arable taxa based on their lifecycle and habitat

of each group and their lifecycle/habitat information, and shows seed count for each group (abundance) and the number of samples in which the groups are present (ubiquity). Figures 7.3a and 7.3b show proportions of the four groups based on their overall abundance and ubiquity.

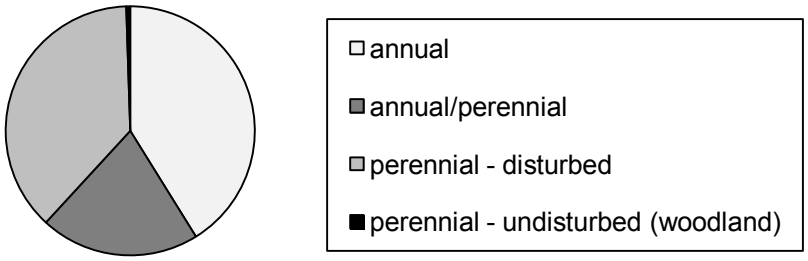


Figure 7.3a Relative proportions of the arable taxa based on their lifecycle and habitat

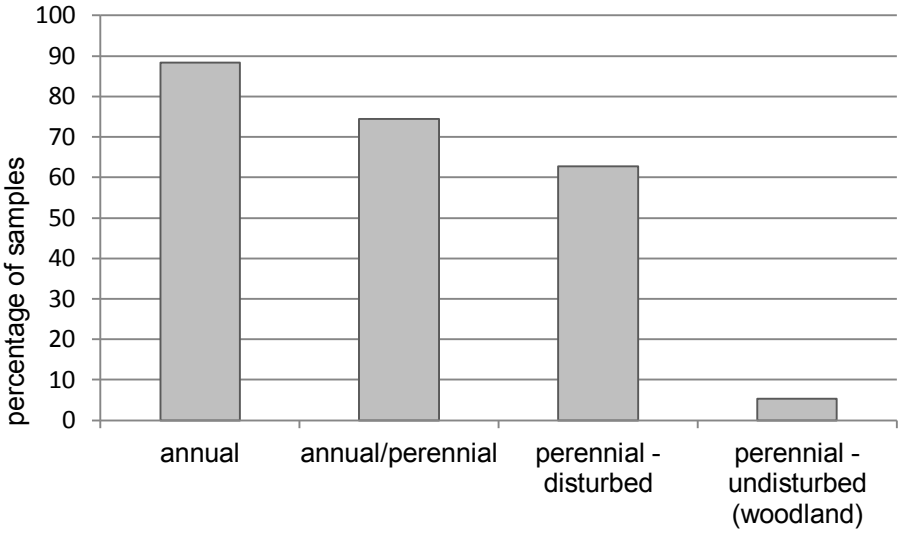


Figure 7.3b Overall ubiquity of the groups of arable taxa

Only five taxa appear restricted to natural (non-athropogenic) habitats, four of them growing in, among other places, woodland. For example, *Potentilla* thrives on rocky/mountain slopes, in forest meadows and alpine pastures, and sometimes in damp places such as edge of streams and lakes. *Viola* grows in *Fagus* forest and scrub, grassy slopes near streams, screes/stony (open and shady) places. *Ranunculus* is characteristic of (coniferous) forests *(Picea, Abies, Pinus, Fagus)* on rocky igneous and limestone slopes, but also of alpine pastures. Shrubby *Polygonatum* is probably the only true specifically woodland taxon, as it occupies *Picea, Pinus nigra, Acer, Fagus orientalis, Castanea sativa* and *Quercus* forest, *Rhododendron scrub* and rocky granite slopes. These four taxa can be representative of natural (woodland)

vegetation of the Konya plain which, according to the landscape and vegetation reconstruction (see Ch. 2), could have grown relatively close to the site, as part of riparian forest, or further away, in case of steppe and/or upland woodlands. In general, they could suggest land newly cleared from woodland for cultivation, managed with no to light tillage and weeding (Bogaard 2002). *Stipa* is an element of undisturbed grassland and perhaps, by analogy with the other taxa of natural habitats, could be indicative of 'clearance' of steppe vegetation. On the other hand, based on the identified role of steppe as a potential grazing area (represented also by e.g. *Artemisia*, see Section 7.2), *Stipa* could (also) belong to the dung-derived assemblage. Due to its ambiguous status, it is eliminated from further discussion.

Except for *Polygonatum*, the four 'undisturbed' perennial (woodland) taxa represent genera comprising many (e.g. more than 10) species, and their lifecycle (and habitat) vary (e.g. *Ranunculus* and *Viola* include annuals and perennials). Moreover, they are extremely rare, each individual taxon occurring in 1-2 samples and as a group in *c*. 5% (5) of the samples; their abundance (both individually and as a group) is also very low (Table 7.3, Fig. 7.3a, b). They could possibly reflect 'opening up' of new permanent fields where perennials, if present, would still be in the vegetative phase or present in the seed bank (for example, *Ranunculus* develops rhizomes from which it could regenerate – J. Hodgson, pers. comm.) and so could survive initial soil preparation (Bogaard 2002, 2004a); another possibility is that these taxa derive from fields situated along the edge of 'woodland' (cf. Maier 2001), as implied by the composition of natural vegetation occupying potential location of cultivation plots (Section 2.3.2.3).

The eight perennials of disturbed habitats are found in *c*. 63% (59) of the samples and are much more common than the perennials of undisturbed habitats. The most abundant (and frequent) among them are *Convolvulus*, *Sideritis* and *Rumex*; all other perennials are present in very low numbers and ubiquities (Table 7.3). Similar to the other taxa potentially derived from anthropogenic environments (e.g. annuals – see below), the majority of taxa within this category are adapted to an array of habitats, from woodland to open steppe. On the other hand, they can all be found in a single habitat type – rocky slopes and hillsides, covered in woodland steppe and/or open oak woodland and scrub (see Ch. 2). The forms of woodland present around Neolithic Çatalhöyük, as documented by the charcoal data, would have included diverse herbaceous woodland species, especially perennials (e.g. *Labiateae* species – Asouti 2005b). In the Hambach Forest weed survey, perennials from disturbed habitats were

particularly numerous in the most disturbed plots (Bogaard 2002). Some of the perennials could not only survive the initial clearance of natural vegetation for agricultural purposes, but also withstand subsequent soil working; a good example is *Convolvulus*, which can easily regenerate from fragments and is adapted to conditions of high disturbance, indicating fixed (intensively cultivated) plots.

The dominant group of arable weeds are annuals/(biennials) of disturbed (ruderal and/or cultivated) habitats. They are present in 88% (83) of the samples and in high proportions (Fig. 7.3a, b); they include a few frequent and abundant taxa, for example *Taeniatherum caput-medusae* (occurring in 72% of the samples). *Taeniatherum* is relatively abundant in the steppe, wasteland and arable weed flora of Central Anatolia (Zohary 1973) and would have been common around Çatalhöyük; it was also noted in oak park woodland at the foothills of the northern Taurus slopes, where intensive browsing and woodcutting has been practised until recently (Asouti 2005b). The taxa from this category would be expected to occur at low levels in shifting cultivation plots (cf. Bogaard 2002); they are, however, dominant in a fixed-plot regime (cf. Ellenberg 1988) and are here understood as weeds of long-lived permanently cultivated fields. The majority of the annual taxa do not exclusively occupy cultivated ground and ruderal places; they also grow in other (less disturbed) areas, such as in open (treeless) steppe, on rocky slopes and hillsides (within woodland steppe), and along edges of rivers and lakes (as part of riparian vegetation). Thus they indicate the type of vegetation zones and soil conditions in which the fields could have been located (see Ch. 2), and/or areas from which these taxa could have invaded the arable fields.

The annual/perennial group comprises 16 genera that include species of variable lifecycle (annual, biennial, perennial and/or annual/perennial) and could not be classified; furthermore, a large number of them include (many) more than 10 possible species (Table 7.3). In terms of habitat preferences, they can all grow in ruderal/cultivated areas, in different woodland and steppe/grassland formations. An exception is the precisely identified *Polygonum convolvulus*, generally considered an annual, but described as perennial in *Flora of Turkey* (Davis *et al*. 1967). It is a common late-flowering climbing weed, also adapted to growing conditions within scrub on rocky slopes and screes.

A vast majority of the arable taxa are consistently associated with, on the one hand, arable/ruderal environment, and on the other – different woodland formations (from relatively

moisture-tolerant riparian 'forest' to woodland steppe and oak woodland on dry soils) and open grassland (grazed and undisturbed steppe, sand, clay and salt steppe). Though analogous observations of the weed species that regenerate after clearance of the woodland formations relevant to Neolithic Çatalhöyük are needed to adapt the model based on the Hambach study, the broad implication is that newly open and low-disturbed fields in woodland would be dominated by woodland perennials. The very low presence of the four natural (woodland) taxa in the Çatalhöyük sample, and their uncertain 'woodland perennial' status, strongly suggest that arable fields were not managed as in shifting cultivation regime. Furthermore, following observations in the German study, if it is inferred that temporary fields in the steppe zone would produce weed flora rich in perennials of non-disturbed steppe vegetation, the general lack of (perennial) taxa restricted to natural grassland in the weed assemblage would also argue against shifting cultivation in the steppe. By contrast, high proportions of taxa of disturbed habitats, particularly annuals, point to cultivation of permanent, highly disturbed plots.

7.3.3 **Sowing time**

Studies of present-day agricultural systems that use 'traditional' methods have been conducted in some parts of south-west Asia and have shown that, following soil preparation (tillage, ploughing), the major winter cereal crops (wheat and barley) are sown in the rainy season - October/November (Ertuğ-Yaraş 1997; Palmer 1998b), while winter legume crops (lentils, bitter vetch) are planted from January onwards (Palmer 1998b). Hillman (1981: 147) states that most crops of traditional farming societies in the Near East are generally autumn-sown whenever possible (when the soil is not exposed to too low winter temperatures without snow cover, and when the time and land is available) because this allows for higher productivity since many varieties require vernalisation (exposure to cold to enable transition from vegetative to reproductive stage - Ullrich 2011: 47) and mature over a long period. Wheats generally have high yields when developing in cool and moist conditions, and ripening in warm and dry periods. Spring sowing is viable for some land races of barley that do not have strong vernalisation requirement and can produce certain yield even with a very short vegetative period (though first domesticated barleys likely required long vernalisation - H. Jones *et al*. 2009; Ullrich 2011: 47). Pulses have a shorter growing season than cereals and are frost-sensitive, so they could be spring sown as is the case today in Central Anatolia and other regions of south-west Asia (Ertuğ-Yaraş 1997; Palmer 1998b). Overall, both autumn-

and spring-sowing of cereals and pulses are possible strategies. Nowadays, autumn-sown cereal crops in Anatolia mature by June (e.g. at Karadaĝ - Fairbairn *et al*. 2005a), barley slightly earlier than wheat, or mid-July in, for example, the Kastamonu region (pers. observation), but they can also become ripe as late as August in eastern parts of Anatolia (Ertuğ-Yaraş 1997; Fairbairn *et al*. 2005a). Fairbairn *et al*. (2005b) have proposed the months of June-July as potential harvest time at Çatalhöyük.

It has been suggested that the ecological composition of weed flora of an autumn-sown crop differs significantly from that of weed flora of a spring-sown crop, even if it is the same crop. Furthermore, it has been demonstrated that crop sowing season can be inferred from weed germination time, and that this approach can be used to assess crop sowing time from archaeobotanical weed assemblages (Hillman 1981:146; Hüppe and Hofmeister 1990; Bogaard *et al*. 2001). Seed germination can be affected by a range of environmental factors such as temperature, water, oxygen and light (day/night length) availability, as well as seed condition (e.g. age, size) and plant genetics (e.g. Silvertown 1981; Baskin and Baskin 1998; Black *et al*. 2006: 126), and precise germination times are not always available (e.g. *Flora of Turkey* does not offer information on germination). However, it is likely that autumn-germinating weeds would grow with winter crops and spring-germinating weeds with spring crops, given that, as part of their broad survival strategy, arable weeds commonly adjust their lifecycle and growing stages to those of crops (Ellenberg 1988; Grime 2002).

Autumn-germinating annual weeds (accompanying autumn-sown crops), which are usually slow-growing, set seed before crop harvest and are potentially harvested with the crops (those that fruit later than crops are removed/damaged by harvest, depending on the harvest method). Spring-germinating annuals, usually faster growing, can also occur in autumn-sown fields and be harvested with the crop. In contrast, autumn-germinating annuals growing in spring-sown fields are mostly destroyed by soil preparation/tillage, giving way to spring-germinating annuals (Ellenberg 1950; Wasylikowa 1981). Since both winter and summer annuals can accompany autumn-sown crops, it would follow that weed-infestation of autumn-sown crops could be greater than that of spring-sown fields; however, if intensive cultivation methods (harrowing, weeding) are applied, there are usually no significant differences in terms of abundance between weed communities of winter and summer crops. However, while intensive cultivation reduces the number of contaminants in general, in autumn-sown fields it destroys winter annuals and encourages summer annuals (Wasylikowa 1981).

Bogaard *et al*. (2001) identified the *onset and length of flowering period* as the most important functional attribute indicating germination time/season (Bogaard *et al*. 2001; Bogaard 2004a). Using a FIBS-based approach, in their study of spring- and autumn-sown crops in Germany, they demonstrated that weed flowering data reflect germination time (e.g. late flowering implies late/spring germination) and that flowering onset and duration can be used as a proxy for distinguishing between autumn and spring germination, and hence the two sowing regimes. More specifically, the study showed that weed species that start flowering between January and June ('early-intermediate onset') and have a short flowering period (set as 1-3 months) are associated with autumn-sown crops. Preparation of soil (ploughing, tilling) for spring sowing would destroy (most of) these weeds and they would not be able to recover in order to be present among spring-sown crops. On the other hand, weed species with late onset of flowering (July or later) are most likely to accompany spring-sown crops; they would not reach maturity by spring, which means they would not be destroyed by spring ploughing, while they would be able to set seed before late summer/autumn harvest. Furthermore, according to this model, species with a long-flowering period (of more than 5 months) would also be associated with spring sowing; they could have early-intermediate onset of flowering but the extended flowering period would enable them to regenerate after spring ploughing (Bogaard *et al*. 2001).

Following observations from the modern study, the Çatalhöyük arable taxa were considered in terms of flowering onset and duration; flowering information was available from *Flora of Turkey* (Davis *et al*. 1965-1988). The weed taxa including more than ten possible species were left out of consideration, and this resulted in 24 (frequent and rare) taxa selected for the assessment. The reconstruction of Çatalhöyük palaeoenvironment suggested warmer climate over the settlement duration (Roberts *et al*. 1999, 2001; Roberts and Rosen 2005), and it is likely that crops would have been ripe slightly earlier than today (Fairbairn *et al*. 2005a). The month of June was therefore assumed as the most likely harvest time, and taxa with flowering onset before, or in/after June were respectively classified as early-intermediate or late onset.

As shown in Table 7.4, 11 out of the total of 24 arable weed taxa (46%) start flowering well before and/or in May (i.e. early-intermediate onset); one taxon has a late flowering onset, while the remaining twelve taxa (50%) can start flowering in the period before, in and after June and are therefore indeterminate. It typically takes up to one month from the onset of flowering to the start of seed production (J. Hodgson, pers. comm.) which means that a

considerable number of taxa (i.e. all taxa with early-intermediate onset, and probably some of the indeterminate) would have been in seed at the time of early-summer harvest.

The duration of flowering was calculated as the maximum number of months over which any individual species included in each taxon tends to flower. Among the 24 taxa, eight have a short flowering period (1-3 months), four have a long flowering period (more than 5 months), while 12 are of medium flowering duration (4-5 months).

In order to assess the potential sowing time, data on the onset and duration of flowering of weeds were combined (Table 7.4). Five taxa with early-intermediate onset and a short period of flowering are understood as likely indicators of autumn sowing of crops. A single taxon with late onset and short flowering could point to the practice of spring sowing. The four long-flowering taxa could also be indicative of spring sowing regime, as in the German study (Bogaard *et al*. 2001), since some of them (e.g. *Convolvulus*) have the ability to recover after disturbance during preparation of soil for spring sowing (e.g. vegetative regeneration - Grime 2002). Five taxa are characterised by medium flowering period and (early-)intermediate onset (i.e. April); in the modern study this category was not indicative of sowing time (Bogaard *et al*. 2001) and here they also remain ambiguous. Nine taxa could not be classified due to the great variation in the considered flowering characteristics.

Relatively few taxa could be classified into an indicative seasonality category based on the flowering onset and duration data presented above. Both autumn- and spring-germinating taxa are present in the assemblage, which could mean that a) both sowing times are represented, b) crops were spring-sown but poorly cultivated (hence autumn-germinating weeds 'survived'), or c) crops were sown in autumn and intensively cultivated, promoting spring-germinating weeds. In principle, long-flowering taxa potentially reflecting spring-sowing could (instead) occur in *intensively* managed autumn-sown fields, as the extended flowering period would (also) enable them to buffer soil disturbance caused by intensive cultivation practices. Late-flowering taxa may also accompany intensively cultivated winter crops since heavy soil disturbance in autumn-sown fields suppresses autumn-germinating weeds and promotes those that germinate later, in spring (Wasylikowa 1981). Notwithstanding the very small number of taxa for which sowing time could be proposed based on the flowering onset and duration, the evidence for autumn-sowing can be considered relatively solid, compared to the ambiguity of the spring-sowing indicators.

TAXA	*possible species within a taxon*	POSSIBLE FLOWERING ONSET												Maximum flowering period (number of months)	Flowering onset class (June cut-off)	German flowering duration class	Onset/duration (June cut-off)	Sowing indicator
		winter			spring			summer			autumn							
		December	January	February	March	April	May	**June**	July	August	September	October	November					
Boreava orientalis Jaub. & Spach	*1*						+							**2**	early-intermediate	short (1-3)	early-int/short	**A**
Conringia orientalis L.	*1*				+									**3**	early-intermediate	short (1-3)	early-int/short	**A**
Cornucopiae cucullatum L. type	*1*				+									**3**	early-intermediate	short (1-3)	early-int/short	**A**
cf. *Lallemantia peltata* L.	*1*						+							**3**	early-intermediate	short (1-3)	early-int/short	**A**
Adonis annua/aestivalis L.	*2*					+								**3**	early-intermediate	short (1-3)	early-int/short	**A**
Capsella Medik.	*2*	+	+	+	+	+	+	**+**	+	+	+	+	+	**12**	early-int./late	long (>5 m)	long	**(S)**
Convolvulus arvensis L. type	*6*					+	+							**6**	early-intermediate	long (>5 m)*	long	**(S)**
Anagallis L.	*2*				+	+		**+**						**6**	early-int./late	long (>5 m)*	long	**(S)**
Malva L.	*9*					+	+	**+**	+					**6**	early-int./late	long (>5 m)*	long	**(S)**
Verbena officinalis L.	*1*							**+**						**3**	late	short (1-3)	late	**S**
Vaccaria pyramidata Medik.	*1*					**+**	+							**4**	early-intermediate	medium (4-5m)	indeterminate	
Taeniatherum caput-medusae L.	*1*						+							**4**	early-intermediate	medium (4-5m)	indeterminate	
Eremopyrum (Ledeb.) Jaub. & Spach	*4*				+	**+**	+							**4**	early-intermediate	medium (4-5m)	indeterminate	
Polygonum convolvulus L.	*1*						+							**5**	early-intermediate	medium (4-5m)	indeterminate	
Lavatera L. type	*6*					**+**	+							**5**	early-intermediate	medium (4-5m)	indeterminate	
Rumex L.	*5*						+	**+**						**5**	early-int./late	medium (4-5m)	indeterminate	
Atriplex L.	*5*						+	**+**						**4**	early-int./late	medium (4-5m)	indeterminate	
Chenopodium album L. type	*5*						+	**+**						**4**	early-int./late	medium (4-5m)	indeterminate	
Hordeum spontaneum C. Koch type	*7*						+	**+**						**5**	early-int./late	medium (4-5m)	indeterminate	
Thymelea passerina (L.) Cosson & Germ. type	*7*			+		+			+		+			**5**	early-int./late	medium (4-5m)	indeterminate	
Androsace L.	*7*					+	+	**+**	+					**4**	early-int./late	medium (4-5m)	indeterminate	
Hordeum murinum L. type	*7*					+	+	**+**						**4**	early-int./late	medium (4-5m)	indeterminate	
cf. *Secale* sp.	*5*						+	**+**	+					**3**	early-int./late	short (1-3)	indeterminate	
Polygonatum Miller	*5*						+	**+**						**2**	early-int./late	short (1-3)	indeterminate	

Table 7.4 Flowering onset and duration information for the selected arable taxa as a basis for the estimation of crop sowing time (A - autumn; S - spring)

7.3.4 **The intensity and scale of arable production**

Intensity of cultivation refers to the level of labour input per unit area of land (Halstead 1987, 1989; Jones 1992; Bogaard 2004a, 2005; van der Veen 2005). Intensive cultivation systems are characterised by high levels of labour investment to increase and/or maintain the productivity of arable land. An extensive cultivation strategy is characterised by low levels of labour input and hence lower yields per unit area compared to intensive systems, but larger net areas of cultivation can result in larger absolute yields (Halstead 1987, 1989; Jones 1992, 2005; Jones *et al*. 1999; Bogaard 2005; van der Veen 2005).

Extensive cultivation is applied to larger areas of land, often at some/considerable distance from the residential area. In extensive systems, cropping is less frequent (i.e. alternating cereals with bare fallow) and there is no particular tending of the crops between sowing and harvesting time; also, large fields are often used for a limited number of crop types (van der Veen 2005). In intensively cultivated fields or 'gardens', a wide range of crops can be grown, from cereals (usually misconstrued as crops necessarily grown extensively and on a large scale - Jones 2005) and pulses, to root and tuber crops, vegetables and herbs (Gregg 1988; Jones *et al*. 1999; Charles *et al*. 2002; Bogaard 2005; Jones 2005).

Nowadays intensive cultivation of cereals is rare, though cereal (spelt and emmer wheat) cultivation on small plots is still practised in some areas, such as the region of Asturias in north-west Spain (Charles *et al*. 2002; pers. observation). Pulses, on the other hand, are regularly cultivated both as field and garden crops, as observed on the Greek island of Evvia (Jones *et al*. 1999). Evvia 'gardens' represented long-term, continuously cultivated, relatively small and scattered fixed plots of winter-sown pulses, located within the village, with larger 'fields' of pulses at some distance from the village. The two main categories of plots were managed differently - intensively or extensively, as demonstrated by different practices relevant to soil disturbance (tillage and weeding) and productivity (watering, fertilising) (Jones *et al*. 1999; Jones 2005). The weed data from the ethnoarchaeological study at Evvia were analysed using FIBS and proved suitable for distinguishing between intensively and extensively cultivated plots (Jones *et al*. 2000a).

The model developed in the Evvia study was tested through application to modern weed data from agricultural plots in Asturias, Spain, where spelt wheat is winter-sown and cultivated on

a small (garden) scale using intensive cultivation techniques (Charles *et al*. 2002). The same functional attributes associated with growing conditions indicative of different levels of cultivation intensity (i.e. duration and quality of the growth period, ability to regenerate under high disturbance – Jones *et al*. 2000a) used in the Greek study were measured for the Asturias weeds. On the basis of quantitative and presence/absence data for the weed species, the measurements for Evvian pulse plots and Asturias cereal plots were compared using discriminant analysis (Charles *et al*. 2002). All but one of the 65 sampled Asturian plots were unambiguously classified as gardens, demonstrating the reliability and suitability of the method for application in different geographical areas and to plots sown with different crops (Charles *et al*. 2002). Moreover, the study demonstrated the potential of a functional ecological approach for identification of the cultivation intensity in the past, based on archaeobotanically attested weeds, by using the same selected suite of functional attributes (e.g. Bogaard 2004a).

In order to explore the crop husbandry regime(s) practised at Çatalhöyük, the weed record was compared to that of the Evvian fields and gardens based on measurements of the functional attributes recognised as the most relevant for differentiating between intensive and extensive cultivation (Jones *et al*. 2000a). Functional attribute data stored in FIBS database at the Department of Archaeology, University of Sheffield, were available for 13 arable taxa of which 11 were identified to fewer than 10 possible species (Table 7.5); seven of these taxa occur in 5 or more samples. Eighty-five samples contained these taxa and were included in the analysis. The two datasets, modern and archaeological, were entered in the discriminant analysis semi-quantitatively, that is, using presence/absence of taxa in each analytical unit (cultivated plot in case of Evvia, sample in case of Çatalhöyük) to ensure comparability. Quantitative data were not suitable since they were obtained in different ways in the two studies; in Evvia study the number of taxon-occurring quadrates was recorded (Jones *et al*. 1999), and in the present study – the absolute number of seeds per taxon (see Ch. 3).

Table 7.6 summarises the results of the discriminant analysis, showing the number of samples classified as gardens or fields with high probability; Figures 7.4a-c illustrate the distribution of Evvia and Çatalhöyük samples in the discriminant analysis. The vast majority of samples (92%, 78 out of 85) were classified as gardens; of those, 92% (72 samples) were classified with high probability (0.9-1). The remaining seven samples were classified as fields, five of them with high probability. The exclusion of samples with 'low' occurrence of FIBS-taxa (i.e.

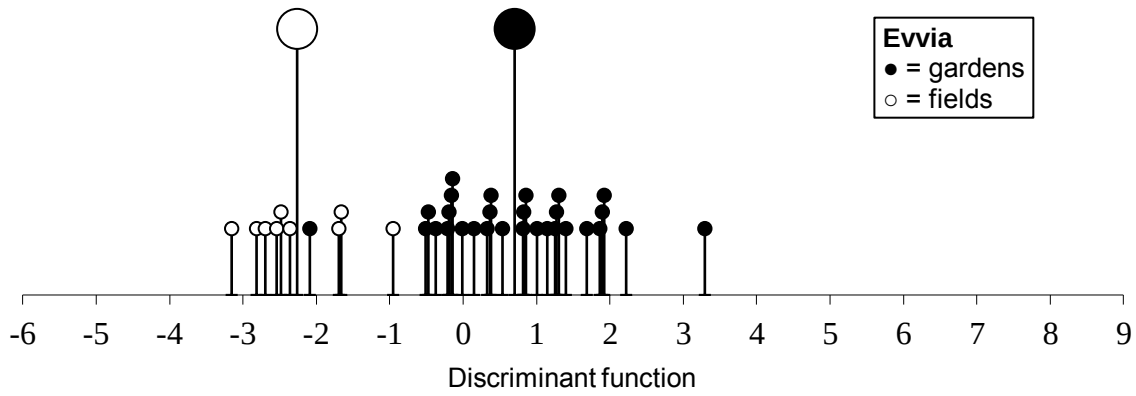


Figure 7.4a The distribution of Evvia pulse gardens and fields in relation to the discriminant function extracted to distinguish between Evvia gardens and fields (large circles = group centroids)

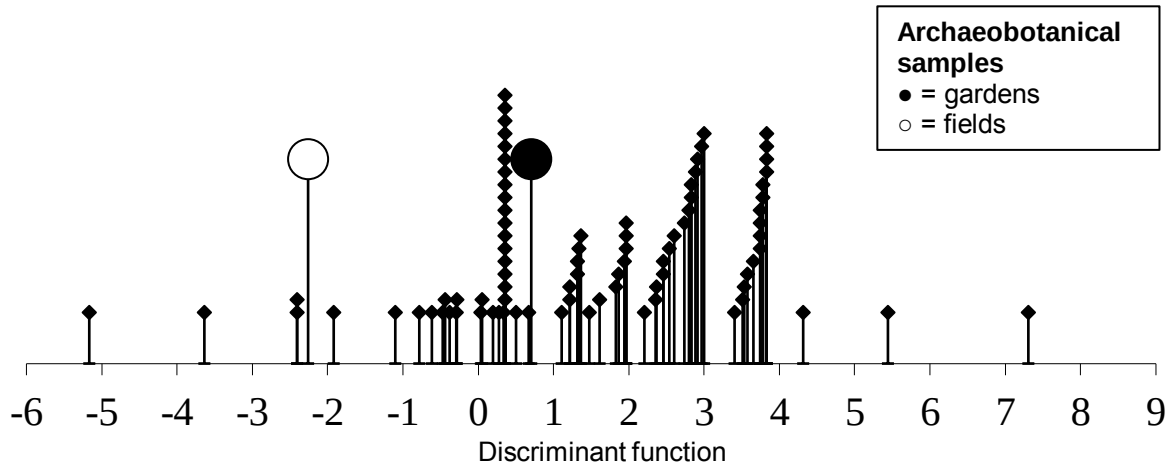


Figure 7.4b The relationship of Çatalhöyük samples to the discriminant function used to discriminate between Evvia fields and gardens (large circles = group centroids)

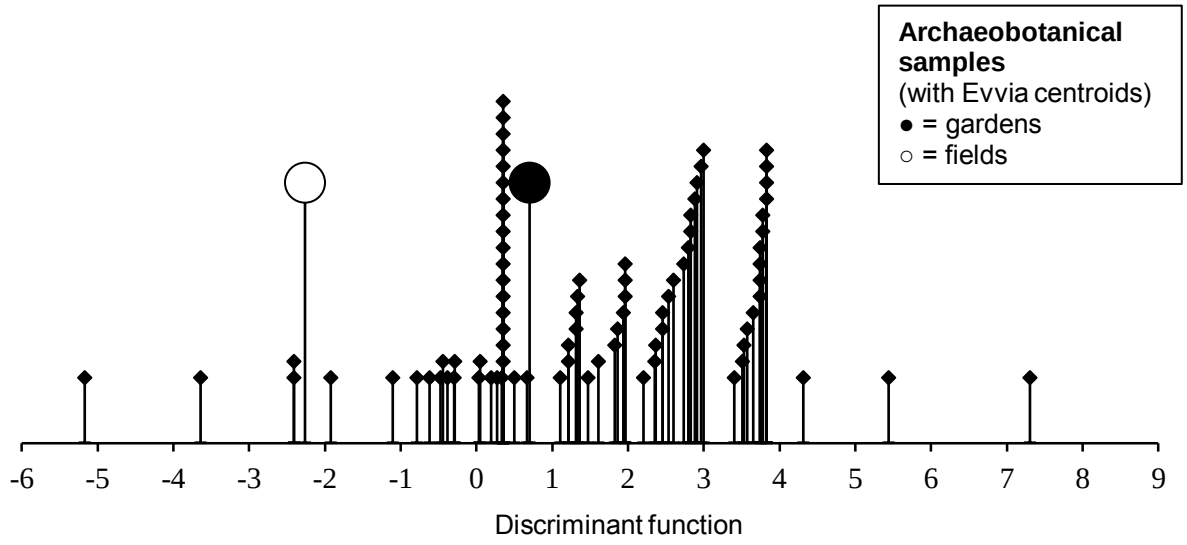


Figure 7.4c The relationship of Çatalhöyük samples to the discriminant function used to discriminate between Evvia fields and gardens plotted with Evvia group centroids

those with fewer than 3) resulted in 45 samples for consideration; in the analysis, these samples were all defined as gardens, 89% (40) of them with high probability. Though a full functional ecological analysis of the data is yet to be completed, these results strongly suggest that the samples derive largely or entirely from intensive cultivation. Furthermore, the intensive cultivation 'signal' is visible through the whole chronological/occupation sequence, and in both South and North excavation areas (Table 7.6).

TAXA	*number of possible species within a taxon*	Ubiquity		Abundance
		count	%	
Verbena officinalis L.	*1*	2	2.13	8
Taeniatherum caput-medusae L.	*1*	68	72.34	617
Vaccaria pyramidata Medik.	*1*	29	30.85	89
Conringia orientalis L.	*1*	10	10.64	34
Polygonum convolvulus L.	*1*	4	4.26	4
Adonis annua/aestivalis L.	*2*	13	13.83	32
Chenopodium album L. type	*5*	8	8.51	69
Convolvulus arvensis L. type	*6*	39	41.49	194
Hordeum spontaneum C. Koch type	*7*	4	4.26	7
Hordeum murinum L. type	*7*	11	11.70	13
Thymelea passerina (L.) Cosson & Germ. type	*7*	9	9.57	27
Galium aparine L. type	*112*	32	34.04	92
Galium verum L. type	*112*	3	3.19	43

Table 7.5 Arable taxa for which FIBS data were available

In terms of scale, intensive cultivation is applied to restricted areas determined by the labour capacity of the work group or family, while extensive cultivation may employ work animals for ploughing and hence attain a much larger aggregate scale (Halstead 1995). Another form of extensive cultivation, shifting cultivation or slash-and-burn, involves relatively low labour inputs in small cultivation areas in any one year plus a much larger area of regenerating (fallow) fields (Bogaard 2002, 2005; van der Veen 2005).

The location of cultivation plots is a key factor determining cultivation intensity, and the location of plots close to the village/house or homestead facilitates intensive farming methods (Jones *et al*. 1999; Jones 2005; Bogaard 2005). As demonstrated by the study of gardens on the island of Evvia (Jones *et al*. 1999; Jones 2005) and recent small-scale farming elsewhere in Greece (Halstead 1987, 1989, 1995, 2000), intensive cultivation involves more intensive care (tillage, repeated weeding, hoeing, manuring, watering etc.) of plots located in the

immediate vicinity of habitation, with a decrease of labour intensity with the distance from home.

The location of Çatalhöyük has been characterised as unsuitable for local/intensive agriculture (Rosen and Roberts 2005; Roberts and Rosen 2009), perhaps resembling traditional Mediterranean rural populations that have lived in nucleated settlements, far from their fields, which, as a consequence, have been extensively cultivated (Halstead 1987, 1989). However, the arable weed evidence presented in this study clearly points to the existence of intensively cultivated, permanent, (dry), autumn-sown fields at Çatalhöyük. The high-labour requirement of intensive cultivation implies that cultivated areas had to be small and situated near the settlement/close to residences.

Ethnographic studies have also shown that intensive cultivation is usually practised by individual households, with the full use of household labour and land in order to provide sufficient produce to satisfy the needs of a small family (Halstead 1987, 1995). The small-scale storage of plant products within Çatalhöyük houses (Bogaard *et al*. 2009; Twiss *et al*. 2009) probably reflects the production of plant products by and for the residential family; so far, no evidence of communal (plant) storage has been detected (Bogaard *et al*. 2009).

The broad set of crops grown at Çatalhöyük may provide further support for a small-scale, garden system which involves (inter)cropping of different crops in contrast to a limited range of crop species cultivated on large fields in extensive systems (Bogaard 2005; van der Veen 2005). To this end, maintenance of a wide range of crops could have been an additional measure for minimizing the risk of subsistence failure (Halstead 1987, 2000).

7.3.5 **Harvesting height and method, and the implications for animal diet and dung use**

As mentioned earlier (Section 5.2.2), reaping/cutting with a sickle (low or high on the straw) and uprooting (by hand or with blunt long-handled sickle used as a lever) of cereals are ethnographically attested harvesting methods in Turkey (Hillman 1981, 1984a). Ear-plucking (harvesting of ears by hand or using a tool, e.g. *mesorias*) and grain-stripping have been documented in recent studies in other parts of the world (Peña-Chocarro 1999; Ibañez *et al*. 2001; P. Anderson, pers. comm.). The finds of sickle elements and sickle handles from the

earliest levels at Çatalhöyük testify that cutting of stalks was practised, though application of other techniques cannot be excluded. For instance, an antler sickle handle lacking its blade inserts was discovered in a bin in Building 18 (Level X/South J), and a similar example was found with obsidian blades in place (Mellaart 1967: 215; Carter *et al*. 2005; Russell 2005: 348-9). The early (Pre-Level XII/South G) deposits yielded the highest number of sickle elements bearing distinctive macroscopic gloss, and made from non-local flint blades; it has been proposed that, at this point in time, these implements may have had a special meaning related to their function, perhaps expressed through the choice of imported ('exotic') material. In the following phases, sickles seem to have been manufactured mainly using locally available and more easily accessible obsidian (Carter *et al*. 2000, 2005). Their apparent rarity in the chipped stone assemblage from the later occupation levels could be due to the less straightforward recognition of obsidian sickle elements, since the silica gloss does not form on the surface of volcanic glass. There is also a possibility that the harvesting method did not involve extensive/frequent use of stone tools (Carter *et al*. 2000, 2005).

The presence/high proportion of cereal culm nodes has been recognised as a potentially useful indicator of the harvesting practice. For example, uprooting or harvesting low on the straw could result in more straw brought on-site and potentially a higher number of culm nodes in the assemblage (Hillman 1981: 150), while the absence/low proportion of basal rachis internodes of cereals may indicate ear-harvesting (i.e. ears are 'snapped' off *above* the basal rachis internode). However, the lack of these cereal stem parts from the assemblage does not necessarily imply any particular harvesting practice since it could be a result of a bias introduced by crop processing and/or charring (cf. Boardman and Jones 1990). The low occurrence of cereal culm nodes, for example, could (also) be a result of crop processing, where they would be discarded early in the processing sequence (Hillman 1981, 1984b; Jones 1984).

A very small number of indeterminate monocot culm nodes, and only one probable cereal culm node were recorded in the analysed samples. As noted previously, the absence of cereal culm nodes could be a result of either ear-harvesting or harvesting low on the straw and removing straw away from the settlement. The absence of samples deriving from the early stages in cereal cleaning (Section 5.3) perhaps indicates that these steps in crop processing took place off-site, eliminating the possibility of finding (a large amount of) culm nodes within on-site charred material. Harvested or not, straw does not appear to have been

transported to the settlement. If it was harvested at the same time as cereal ears, it could have been removed in off-site crop processing and perhaps used away from the site. It could have also been harvested separately from ears or simply left in the fields and grazed by animals (see below).

The (off-site) use of straw may include its role as temper in mudbrick and 'mortar' production (e.g. Stevanović 1997; Çilingiroğlu *et al.* 2004: 31; Erkal 2006: 205-206). However, analysis of plant content of the construction materials used at Çatalhöyük, mainly preserved in the form of silica remains (phytoliths), showed that, in contrast to commonly found cereal chaff, straw is entirely absent from the mudbricks (Ryan 2008, 2011; Bogaard *et al*. 2008, in press/2013). The main plant materials used in construction were leaves and stems of wild grasses, reeds and sedges, and cereal husks (i.e. cereal chaff from the ear) (Ryan 2011). Moreover, the amounts of cereal straw phytoliths are generally low across the site, both in a wide range of sampled contexts (floors, fire installations, middens) and in dung pellets (Ryan 2011). The low occurrence of straw phytoliths in fuel remains (i.e. in ashy residues from fire installations) indicates that straw was not generally used as fuel, or eaten by animals from which dung used as fuel was collected (as it would have potentially been preserved in dung in silicified form – e.g. Kühn and Hadorn 2004; Linseele *et al*. 2010), nor used as temper in dung cake manufacture (Ryan 2011).

In order for weed seeds to arrive on site with the grain, the cereals must have been harvested below the maximum height level of the arable weed taxa. Therefore, stem-heights of the arable weeds were examined as an indicator of the harvesting height. Table 7.7 lists maximum stem heights (extracted from *Flora of Turkey* - Davis *et al.* 1965-1988; Güner *et al*. 2001) for the weed taxa that include up to ten possible species; these taxa are present in 85 samples. *Convolvulus* and *Malva* remain indeterminate, since the height of the possible species varies from short/medium to tall.

The height of other weed taxa in the assemblage was assessed using arbitrary categories. The cut-off for classification of the weeds as 'short' was set at ≤35 cm; 'medium' taxa were defined as having a maximum height between 36 cm and 80 cm, and 'tall' taxa as >80 cm high. The very small number of short taxa (three out of 24) perhaps shows that the cereals were only seldom cut (sickle-harvested/reaped) close to the ground. The eight medium taxa suggest reaping higher on the stem. The eleven tall taxa could accompany both sickle- and

TAXA	*number of possible species within a taxon*	min. stem height (cm)	**max. stem height (cm)**	**Classification**	**Ubiquity**		Abundance
					count	%	
Eremopyrum (Ledeb.) Jaub. & Spach	4	4	30	short	23	24.47	43
Boreava orientalis Jaub. & Spach	1	15	30	short	8	8.51	20
Androsace L.	7	1	30	short	5	5.32	39
				SHORT	**30**	**31.91**	**102**
cf. *Lallemantia peltata* L.	1	15	40	medium	3	3.19	5
Cornucopiae cucullatum L. type	1	8	47	medium	21	22.34	85
Capsella Medik.	2	4	50	medium	1	1.06	1
Taeniatherum caput-medusae L.	1	5	50	medium	68	72.34	617
Adonis annua/aestivalis L.	2	10	50	medium	13	13.83	32
Vaccaria pyramidata Medik.	1	15	60	medium	29	30.85	89
Conringia orientalis L.	1	19	60	medium	10	10.64	34
Anagallis L.	2	2	70	medium	2	2.13	7
				MEDIUM	**81**	**86.17**	**870**
Thymelea passerina (L.) Cosson & Germ. type	7	6	150	tall	9	9.57	27
Hordeum murinum L. type	7	10	100	tall	11	11.70	13
Hordeum spontaneum C. Koch type	7	10	100	tall	4	4.26	7
Polygonatum Miller	5	15	100	tall	1	1.06	9
Verbena officinalis L.	1	30	100	tall	2	2.13	8
Polygonum convolvulus L.	1		100	tall	4	4.26	4
cf. *Secale* sp.	5	50	110	tall	1	1.06	1
Chenopodium album L. type	5	5	150	tall	8	8.51	69
Atriplex L.	5	30	150	tall	20	21.28	168
Rumex L.	5	10	200	tall	23	24.47	559
Lavatera L. type	6		300	tall	12	12.77	14
				TALL	**54**	**57.45**	**879**
Convolvulus arvensis L. type	6	3	300	indeterminate	39	41.49	194
Malva L.	9	25	100	indeterminate	8	8.51	12
Viola L.	21	3	30	short	1	1.06	1
Fumaria L.	15	10	40	medium	5	5.32	10
Valerianella Miller	21	3	40	medium	2	2.13	3
Erodium L'Hérit.	29	2	50	medium	2	2.13	2
Ranunculus L.	78	3	70	medium	2	2.13	2
Papaver L.	36	10	90	tall	1	1.06	2
Teucrium L.	30	3	100	tall	4	4.26	21
Geranium L., small type	33	5	100	tall	1	1.06	1
Linum L.	38		100	tall	1	1.06	13
Sideritis L. type	43	3	100	tall	26	27.66	291
cf. *Potentilla* L. type	53	3	100	tall	2	2.13	3
Bromus danthoniae Trin. type	35	5	150	tall	34	36.17	80
Silene sp.	100+	3	150	tall	20	21.28	214
Galium aparine L. type	112	3	180	tall	32	34.04	92
Galium verum L. type	112	3	180	tall	3	3.19	43
Vicia L./*Lathyrus* L.	100+	5	250	tall	18	19.15	31
Euphorbia L.	93	3	300	tall	1	1.06	2
Centaurea sp.	c. 200	5	300	tall	12	12.77	31

Table 7.7 Classification of the selected weed taxa based on the maximum stem height

ear-harvested cereals. It is worth noting that three of the tall taxa are considered 'headed' in terms of their seed properties relevant to crop processing (Section 5.3.2) and that, in ear-harvesting, they may be more visible/avoidable than the 'non-headed' taxa; they are indeed rare - only one (*Lavatera*) is present in over 5% of the samples. On the other hand, very few climbing weeds were recorded – e.g. *Polygonum convolvulus* and *Vicia/Lathyrus* (the second not considered due to large number of possible species within the taxon). Among the taxa not included in the assessment, the majority could be considered tall (Table 7.7). Figure 7.5a shows relative proportions of the three height-based groups of taxa in the assemblage; Figure 7.5b illustrates overall ubiquity of the weed classes in the samples. Whereas the medium-height and tall taxa are present in similar proportions, medium taxa are the most frequent; short taxa occur in very low proportion and in a small number of samples.

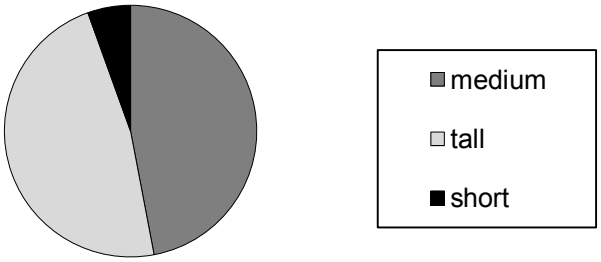


Figure 7.5a Relative proportions of the arable weed taxa classified according to their stem height

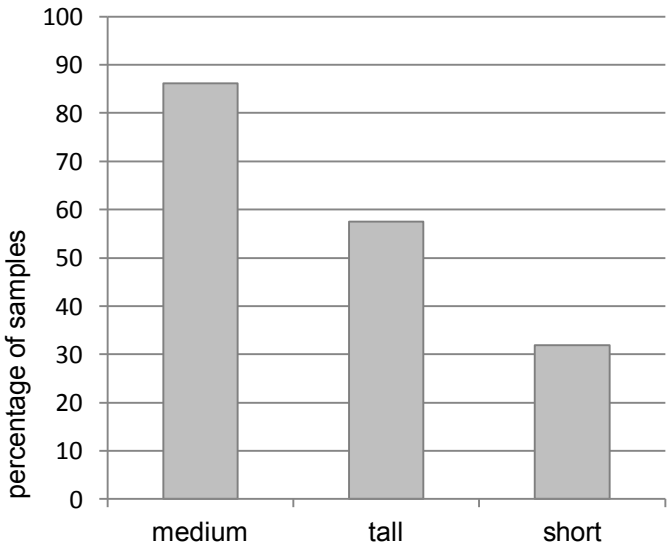


Figure 7.5b Overall ubiquity of the arable weed taxa classified according to their stem height

Based on the prevalence of the medium to tall taxa, it could be argued that sickle-harvesting was the dominant harvesting method at Çatalhöyük, and that cereal stems were cut about 40-80 cm above the ground. Medium and tall weeds would be harvested at this height, while low-growing weeds could occasionally be included, when harvesting height falls below 40 cm (but probably not lower than 30 cm – the maximum height of short weeds, Table 7.7). An analogy can be observed with the better preserved evidence from the late Neolithic site of Hornstaad-Hörnle in Germany (Maier 1999, 2001). Here, finds of stores of complete cereal ears with attached straw (i.e. fragments of the highest culm), and overall rarity of culm nodes, led to a conclusion that harvesting high on the straw, above the highest culm node (some 10-20 cm under the ears) was most probably practised (Maier 1999: 92). Furthermore, as in the Çatalhöyük weed record, medium-tall weeds (above *c*. 40 cm in height) were predominant at Hornstaad-Hörnle (Maier 2001: 98-100). It is possible that, at Çatalhöyük a similar harvesting method was applied – reaping relatively high on the straw, above the highest culm node. Though advantageous in terms of weed avoidance, ear-harvesting is a slow method compared to reaping, and appears particularly suitable for e.g. wet mountainous zones, where crop ripening is relatively uneven and prolonged, and straw is not used due to difficulties in the transport (Ibañez *et al*. 2001). In flat areas (e.g. plains) crops ripen at about the same time, and harvesting using sickles ensures rapidity of the process, because, once ripe, crops become prone to scattering of the grain by birds, wind, and by harvesting itself (Halstead 2006).

It is striking that the remains of specific (on-site and off-site) activities from the early-mid Çatalhöyük occupation sequence in which straw could have been used (e.g. basketry and other crafts, construction, fuel burning, foddering) do not include straw phytoliths (Ryan 2011); likewise, no evidence pointing to existence of 'stores' of straw has been discovered at the site. This, combined with the general absence of cereal type culm nodes, suggests that straw was not a (widely) used resource within the settlement. The harvesting method identified on the basis of the (maximum) height range of arable weeds – harvesting high on the straw – suggests that the main goal of the farmers was to retrieve the ears, while at the same time avoiding shattering of fully ripe grain, and generating minimal straw to be transported to the threshing floor and discarded in crop processing.

In terms of animal diet, it appears that instead of straw, (wetland) vegetation available close to the site have been the primary forage source, as suggested by the analysis of dung-derived plant material (see also Henton 2012). Sedges and rushes would have provided fresh leaves

and stems for grazing over much of the year (from mid-spring till late autumn – Section 7.2.2), while they are also storable as winter fodder, or to be used for non-food purposes (e.g. as raw materials) as and when needed (e.g. Ertuğ-Yaraş 1997; Erkal 1999, 2006; Rosen 2005; Ertuğ 2006; Ryan 2011). However, the lack of straw remains in dung-containing deposits does not imply that straw was not in use as animal feed, since, if not brought to the settlement and used *on-site*, straw could have been consumed *off-site*. For example, if left in the field, straw would have been available for caprine grazing, which, in turn, would have provided manure for the plots, improving the soil fertility and crop productivity. If this was the case, then the absence of straw from on-site dung residues (in the form of straw fragments if dung unburned, or straw phytoliths – e.g. Kühn and Hadorn 2004; Linseele *et al*. 2010) would mean that dung intended for fuel has not been collected from stubble-grazing sheep/goats (perhaps kept in fenced arable plots). This could further imply that perhaps only selected parts of the herd had access to cereal stubble (e.g. sheep fattened for winter cull – Henton in press/2013), whereas the remaining sheep/goat grazed on wetland vegetation/field edges (and produced collected dung). It is also possible that there was no discrimination within the herd(s) in terms of grazing sources, but that dung was not collected during the time of the year when stubble was available (perhaps in line with the highly labour-demanding post-harvest season), or that it was not collected from these particular areas.

The seasonality and location of dung collection was noted in some ethnographic accounts, which describe the practice of keeping sheep in stables from late autumn/early winter and letting the droppings and urine accumulate and be trampled by sheep over this period; once sheep leave the stables in spring, the layer of dung (the 'dung floor') is left to dry and subsequently (in June/July) lifted or broken up into pieces and taken out for additional drying in the sun, followed by storage (Ertuğ-Yaraş 1997: 362-363; Anderson and Ertuğ-Yaraş 1998; also Fenton 1985: 105; Reddy 1997; Charles 1998). This may be convenient as it is not necessary to collect dung scattered around grazing areas, which, in the case of sheep/goat pellets could be a very time-consuming task due to their morphology (unlike e.g. cow dung), though it was, for instance, widely practiced in the 19th century Denmark (Fenton 1985: 105-107). The use of stall dung allows cutting of dung into transportable and storable pieces (plates or brickets – Fenton 1985; Reddy 1999). Moreover, the vegetal content of dung can in this way be controlled by selective grazing/foddering, since straw may not be a desirable addition to dung fuel (in some places straw was considered to diminish the fuel quality – Fenton 1985). Deposits of compressed herbivore dung, resembling those from the

ethnographical examples of roofed pens for stalling of sheep and goat over winter, have been identified at some locations at Çatalhöyük (Matthews 1999, 2005a) perhaps indicating similarities in the practice of dung collection and use.

In summary, much of the straw at Çatalhöyük could have been left in arable fields and could have represented a source of food for sheep/goats; dung of stubble-grazing animals could have had its immediate application as (fresh) manure. Additional manure would have been available from animal pens/stalls in the form of trampled dung, or in the form of ashes from burnt dung (Fenton 1985); ethnographic examples in Central Anatolia show regular use of dung for both fuel, and fertilizer (as well as other purposes – Ertuğ-Yaraş 1997). There are other examples from the recent past of 'recycling' of dung, where it was first spread on the land as manure and left there for few weeks ('till the juices had sunk in') and then collected, dried and used as fuel (Fenton 1985: 107-108).

7.3.6 **The location of arable fields**

According to the previously proposed palaeoenvironmental model (Ch. 2), backswamps and marshes dominated the landscape around Çatalhöyük due to the annual (late spring) flooding across the Çarşamba alluvial plain in which the site was located. As a result of regular flooding and alluviation, fine-grained soils (silts and clays) were deposited on top of the 'impermeable' Pleistocene lake marl in the vicinity of the settlement (in a radius of *c*. 10 km around the site), and due to the lack of natural water outflow much of this area was inundated throughout spring, while some parts stayed wet for longer periods, resulting in slow evaporation and soil salinisation (Driessen and de Meester 1969; de Meester 1970, Driessen 1970; Roberts *et al*. 1996, 1999; Rosen and Roberts 2005; Boyer *et al*. 2006; Roberts and Rosen 2009).

Therefore, unlike many other Neolithic sites in south-west Asia where farmers took advantage of rich alluvial soils in floodplains (Sherratt 1980; Colledge 2001), in this reconstruction the flat low-lying land in the Çarşamba catchment was inaccessible and unsuited for agriculture. The closest areas of dryland would have been sand ridges *c*. 7 km away, probably not very suitable for crop cultivation due to their fast-drainage and low nutrient status (Driessen and de Meester 1969; Rosen and Roberts 2005; Roberts and Rosen 2009). The hill-zone (limestone terraces), volcanic slopes and dry steppe beyond the Çarşamba fan represent more substantial

areas of dry soils, however, their distance of some 13 km from the settlement (i.e. well beyond the 5 km daily commute route) suggests that they would not have been agriculturally viable locations (Vita-Finzi 1969; Higgs and Vita-Finzi 1972; Asouti and Fairbairn 2002; Fairbairn *et al*. 2005, Fairbairn 2005; Rosen and Roberts 2005; Roberts and Rosen 2009), unless parts of the population ('task groups') spent time away from the settlement, e.g. in temporary structures near the fields, in order to take care of the crops (Roberts and Rosen 2009).

More recent geomorphological work (the current Landscape and Coring Programme) suggests that the water-retentive lake marl was unevenly distributed in the area around Çatalhöyük, and that it was inter-stratified with Pleistocene sands, silts and clays; these sediments would have allowed relatively quick penetration of the surface water, resulting in (greater) availability of dry land near the site (Doherty *et al*. 2007, 2008; Doherty in press/2013). Various mudbrick analyses also indicate greater diversity of the clay sources (Matthews 2005a; Tung 2005; Doherty 2007; Doherty and Camizuli 2008). Such sediments cannot be accommodated in the area around the site in the geomorphological reconstruction by Roberts *et al*. (1996, 1999; Boyer *et al*. 2006); they may relate to raised dry-land areas potentially protruding from the flooded surrounding (Baird 2002; Fairbairn 2005; Boyer *et al.* 2006) for example in the form of marl hummocks remaining from the former lake. Indeed, the recent coring data point to an existence of large marl hummocks to the south and north of the site (Doherty *et al*. 2008). Though lacustrine soils are nowadays regarded as having generally poor agricultural quality, some marl types are relatively productive (Driessen and de Meester 1969) and they could have represented a cultivation zone in close proximity to the site.

Another possible location of cultivable land is along the Çarşamba watercourse, where sedimentation, especially in flooding season when flow velocities would have been high and intensive, would lead to build-up of natural ridges of alluvium (levees) parallel to the river banks (Driessen and de Meester 1969; Kemp 1998: 228; Baird 2002; Fairbairn 2005; Arnoldussen 2008). As a result of the regular deposition of the material, levees would have probably been reasonably higher than the adjacent flat floodplain, and less subject to (frequent and prolonged) flooding, allowing formation of a layer of top soil rich in decaying vegetative organic matter providing nutrients to the soil (Brown 1997). These raised surfaces would have represented (additional) dry land close to the settlement (i.e. within the 5 km radius), regularly replenished by nutrients via continuous sedimentation of alluvium when the river overflows

its banks during flood, more so if they were made up of well-drained coarse sand (Driessen and de Meester 1969; Brown 1997; Kemp 1998: 228; Asouti and Hather 2001; Arnoldussen 2008).

The 'islands' of dry land (e.g. marl hummocks, levees) were the most likely cultivation areas, probably from the early stages of habitation. There is not yet adequate data to allow estimation of their actual extent in the site's vicinity, though new geomorphological results indicate that the Neolithic landscape was probably less prone to flooding than previously proposed (Doherty *et al*. 2008; Charles *et al*. in press/2013). The present-day sub-surface sand and clay-loam deposits identified in the Çarşamba basin (Driessen and de Meester 1969; de Meester 1970) could represent buried levees/ridges from the past and could perhaps serve as a rough indicator of the potentially available cultivable land spanning the several-kilometer radius around Çatalhöyük (Baird 2002; Fairbairn 2005). However, the dynamics of active fluvial landscapes (cf. Arnoldussen 2008) such as river meandering, levee collapse, and the continuous and substantial flooding and alluvium deposition for most of the Çatalhöyük history (Roberts and Rosen 2005; Boyer *et al*. 2006; Roberts and Rosen 2009), may have resulted in contraction of the extension and changes in the distribution of available dry land over time (Baird 2002: 141; 2005; Fairbairn 2005; Boyer *et al*. 2006: 685). It has therefore been suggested that the variable alluvial landscape required opening-up of new crop fields in freshly occurring viable agricultural areas (Fairbairn 2005); this could potentially lead to overall instability of arable production. The Çatalhöyük archaeobotanical evidence (Fairbairn *et al*. 2005; Bogaard *et al*. in press/2013; present study), however, points to a reliable production system and continuity of crop cultivation at the site.

The reconstruction of the distribution of vegetation forms in the site's surrounding and, in particular, the abundance/frequency of woodland vegetation based on the charcoal record (Asouti and Hather 2001; Asouti 2005b), could perhaps argue against the practice of opening up of new fields every few years. While the periodically inundated surfaces around the site (unsuited for the agriculture) would have been home to grasses, sedges and rushes, and water- and salt-tolerant woodland taxa (such as alder and tamarisk), the occurrence of riverine forest taxa (e.g. willow/poplar and elm), as well as tree taxa typical of woodland steppe and park woodland (oak, juniper, woody legumes, hackberries, terebinth, almond etc) would have only been possible on well-drained, coarse-textured soils (with low water table) – such as dry sand/clay ridges and levees (Zohary 1973; Hillman 2000a; Asouti 2003, 2005b). As noted

above, these are precisely the same areas most likely used for arable cultivation. The charcoal data show no evidence for the disappearance of riparian forest taxa (such as poplar, willow, elm, ash, caper) in the later occupational phases (Asouti 2005b). The uninterrupted availability of wet woodland vegetation suggests continuous presence of raised alluvial surfaces around the site. Had the crop fields covered substantial portions of these areas, or if new plots were laid down every couple of years, this would likely have adverse affect to the woodland vegetation, additional to potential disturbance from flooding. This, and the pressure from woodland management for firewood would have largely hindered the capacity for woodland regeneration, leading perhaps to its discontinuation (Asouti and Hather 2001; Asouti 2005b). Occasional small-scale clearance of woodland and cultivation of permanent plots would have much less impact on the extent and diversity of original vegetation.

On the other hand, oak and other taxa associated with park woodland and woodland steppe, whilst constantly present in early levels, become more frequent in later phases of early-mid sequence (from Pre-Level XII.A/South G onwards), perhaps indicating well-developed oak woodland growing in close proximity to the site, in expanding dry zones of the alluvium, or exploitation of fuel and timber sources from greater distances (sand ridges, colluvial slopes) (Asouti 2005b). While oak continues to dominate the assemblage in Levels IX-VII/South K-M, the frequency/abundance of juniper increases through time (from Level IX/South K onwards), and it gradually replaces oak, becoming probably the dominant taxon at Çatalhöyük West (and Chalcolithic Pınarbaşı B - Asouti 2003, 2005b). The progression of juniper could be a result of gradual development of generally drier conditions with lower precipitation at around 7000 cal. BC, as documented by palaeoenvironmental data (Roberts *et al*. 2001), causing a retreat of oak woodland; an additional reason could be the invasive nature of juniper which replaces oak in areas used for animal grazing/browsing and/or logging over an extended period (Asouti and Hather 2001; Asouti 2005b). In any case, the noted oak abundances perhaps signal the presence of larger areas of dry land in site's vicinity, which would have been suitable for crop cultivation.

7.3.7 **Cultivated land area and cereal yields**

Intensive garden cultivation assumes higher area yields obtainable from smaller cultivation areas compared to, for example, extensive ard cultivation (Halstead 1995; Bogaard 2004a: Table 2.1). There are a number of estimates of crop yields based on experimental and/or

historic data for shifting and extensive cultivation (cf. Bogaard 2004a: Table 2.1), but not many relevant data on area yields in intensive cultivation systems, probably due to the general decline in use of the respective traditional methods, and lack of experimental studies. Nonetheless, some information from ethnographic work in Europe (Jones *et al*. 1999; P. Halstead Asturias field notes, cited in Bogaard 2004a; Hajnalová and Dreslerová 2009) on traditional cereal cultivation provide certain clues for estimates of the extent of the cultivated area and approximation of the crop yields during the early-mid Neolithic occupation of the settlement at Çatalhöyük East.

The extent of the cultivated land per household or a population largely depends on the area yields and dietary requirements/preferences (see e.g. Bogaard 2004a: Table 2.2). The calculations of the required cereal yields and cultivated land for the early-mid Neolithic Çatalhöyük population provided here are based on the following:
1) the population number projections provided by Cessford (2005): based on the number of buildings/households and the likely number of occupants (four to nine individuals inferred from the estimated sleeping arrangement) the estimated population values range between 3500 and 8000 people. The figures calculated using population densities of 100-200 people per hectare vary between 1356 and 2712, overlapping with the lower end of the building-based estimates. The closely spaced buildings, however, suggest a higher population density. For the present calculations, the lower end of the population estimate is set at 1000 to take account of a possibly small(er) community that founded the settlement at Çatalhöyük.
2) the projections of the annual requirement in cereals per person and per household suggested by Bogaard (2004a): if cereals comprised as much as 80% of diet, then the required amount per person per year would have been around 300 kg of cereals - i.e. *c*. 2500 kcal per person per day (given that 1 kg of wheat provides *c*. 3000 kcal - Gregg 1988). The household of five, for example, would then need to secure 1500 kg cereals per year.

Long-term experimental crop studies at Woburn, Rothamsted and Little Butser Farm have shown that annual wheat yields of about 1000 kg/ha are achieved from permanent fields without manuring, and significantly more (e.g. over 3500 kg/ha) if manure is applied (Bogaard 2004a: Table 2.1). Modern-day small-scale intensive spelt (*Triticum spelta* L.) cultivation documented in the region of Asturias, north-west Spain, secures around 1700 to 1900 kg/ha, and a minimum of 800 kg/ha when yields are poor; Asturian farmers practice

regular manuring and hand-weeding (Charles *et al*. 2002; P. Halstead Asturias field notes, cited in Bogaard 2004a; pers. observation). In the ethnographic study of small-scale traditional farming in Transylvania, documented einkorn yields from traditionally farmed manured fields were around 1300-1400 kg/ha (Hajnalová and Dreslerová 2010).

Çatalhöyük population	**1000**	**2000**	**3500**	**5000**	**6500**	**8000**
Density (people/ha)	*74*	*147*	*257*	*368*	*478*	*588*
	ANNUAL CEREAL REQUIREMENT OF THE POPULATION (kg)*					
	300,000	600,000	1,050,000	1,500,000	1,950,000	2,400,000
AREA YIELD (kg/ha)	**REQUIRED LAND (ha)**					
400	750	1500	2625	3750	4875	6000
500	600	1200	2100	3000	3900	4800
600	500	1000	1750	2500	3250	4000
700	429	857	1500	2143	2786	3429
800	375	750	1313	1875	2438	3000
900	333	667	1167	1667	2167	2667
1000	300	600	1050	1500	1950	2400
1100	273	545	955	1364	1773	2182
1200	250	500	875	1250	1625	2000
1300	231	462	808	1154	1500	1846
1400	214	429	750	1071	1393	1714
1500	200	400	700	1000	1300	1600
1600	188	375	656	938	1219	1500
1700	176	353	618	882	1147	1412
1800	167	333	583	833	1083	1333
1900	158	316	553	789	1026	1263
2000	150	300	525	750	975	1200

***** if 300 kg of cereals required per year per person

Table 7.8 Calculations of the required arable land for different population estimates at Çatalhöyük; highlighted: area of/about 1000 ha, and area of/about 2000 ha

A range of possible area yields, from as little as 400 kg/ha - comparable to the reported minimum of 480 kg/ha wheat yield from non-manured continuously cropped plots at Woburn, and 450 kg/ha barley yield from non-manured continuously cropped plots at Rothamsted (Bogaard 2004: Table 2.1) - to as much as 2000 kg/ha, are used in the calculations of the required land for different population levels at Çatalhöyük (Table 7.8). For a lower estimate of 1000-2000 people, it seems that a relatively small area of about 1000 ha or less would have been sufficient for the whole population even assuming very low yields (400-600 kg/ha). From the arable land of the same size, yields of between 1500 and 2000 kg/ha would have had to be obtained for a population of 5000-6500, and more than 2000 kg/ha for the maximum projected population of 8000. On the other hand, high yields of ≥1500 kg/ha, which could

have been secured by manuring and intensive management, would have considerably reduced the necessary area for cultivation (see Table 7.8).

The area within the 5 km radius around Çatalhöyük as an arbitrary limit of efficient agriculture (Fairbairn 2005: 200) encompasses 7850 ha of land (measured from the centre of the mound). If 25% of this area were cultivable, as suggested by Fairbairn based on the modern soil maps (2005: 200), then *c*. 2000 ha (1962.5 ha) would have been available. Table 7.8 shows that that *c*. 2000 ha of land would have satisfied the needs of a very large population even if producing 'medium' yields of e.g. 1000 kg/ha, comparable to those from the experimental permanent plots cultivated without manuring (see above). However, in the examples of traditional agriculture practised in Evvia (Jones *et al*. 1999), arable plots cultivated with a high to medium intensity (back and allotment gardens, fenced fields and vineyards, respectively) were located within a much smaller radius of settlement, up to 2500 m away. In application to Çatalhöyük, if, for example, 80% of land within the 2 km radius (i.e. about half an hour distance or less) around the site (measured from the centre of the mound) were cultivable - i.e. *c*. 1000 ha (1004.8 ha) - then, as noted, significantly higher yields of more than 2000 kg/ha would have had to be achieved for the population of above 6500 (Table 7.8). By analogy, data from the experiments at Woburn, Rothamsted and Little Butser farms register yields of 3000+ kg/ha obtained from manured, continuously cropped barley and wheat plots, of which some were under cereal-pulse rotation (Bogaard 2004a: Table 2.1). Table 7.9 shows the projected distances to which Çatalhöyük residents would have had to travel to their fields, in relation to the varying cereal yields (assuming that 300 kg of wheat - 80% of diet - was required per person annually, see Table 7.8). Interestingly, it appears that even a small population of 1000 people would have needed to travel over 1 km to the fields if producing less than 1000 kg/ha. Moreover, a large population of 8000 would have needed to travel 2 km and increasingly more, unless it has been capable of attaining 2000+ kg of cereals per hectare of land.

It is likely that the annual cereal requirements varied among Çatalhöyük households (and residents), and may have not been as high as projected. Furthermore, production levels would have been different from one household to another, depending on the presence/absence and the level of intensity of certain agricultural practices, i.e. the thoroughness of tilling and weeding, sowing by broadcasting or dibbling, manuring etc as, for example, observed in Evvia (Jones *et al*. 1999: Table 2). The factors influencing the cultivation intensity and,

consequently, the production levels would include the size and distance of cultivated plots, and available labour per household.

Çatalhöyük population	1000	2000	3500	5000	6500	8000
ANNUAL CEREAL REQUIREMENT OF THE POPULATION (kg)*	300,000	600,000	1,050,000	1,500,000	1,950,000	2,400,000
AREA YIELD (kg/ha)	**DISTANCES TO FIELDS (m)****					
400	1545	2186	2891	3456	3940	4371
500	1382	1955	2586	3091	3524	3910
600	1262	1785	2361	2822	3217	3569
700	1168	1652	2186	2612	2979	3304
800	1093	1545	2044	2444	2786	3091
900	1030	1457	1928	2304	2627	2914
1000	977	1382	1829	2186	2492	2765
1100	932	1318	1744	2084	2376	2636
1200	892	1262	1669	1995	2275	2524
1300	857	1212	1604	1917	2186	2425
1400	826	1168	1545	1847	2106	2337
1500	798	1129	1493	1785	2035	2257
1600	773	1093	1446	1728	1970	2186
1700	750	1060	1403	1676	1911	2120
1800	729	1030	1363	1629	1857	2061
1900	709	1003	1327	1586	1808	2006
2000	691	977	1293	1545	1762	1955

***** if 300 kg of cereals required per year per person

****** radius measured from the centre of the mound

Table 7.9 Calculations of the distances which Çatalhöyük residents would have travelled to their fields, in relation to the varying cereal yields and for different population levels

Based on the estimated sleeping arrangements in Çatalhöyük buildings, four to nine individuals have been suggested as the likely number of occupants/household members (Cessford 2005). Table 7.10 presents the required land per households of various sizes and for a range of cereal yields. Figure 7.6 illustrates the relationship between the number of household members and the area yields. As previously observed (Bogaard 2004a: 42, Table 2.2), the higher the area yields - the smaller the cultivated area needed per household. Moreover, based on Figure 7.6, it appears that the higher the area yield, the less relevant the number of people per household. For example, at area yields of 1200 kg/ha a hectare of land is potentially sufficient for a four-member household, while at 1500 kg/ha the same plot could cover the needs of a five-member household. A considerably large cultivated area (i.e. ≥2.5 ha) yielding less than 1000 kg/ha would be needed to support a nine-member household, whereas the area figure drops to below 2 ha if obtainable yields are 1500 kg/ha or more.

	PEOPLE PER HOUSEHOLD					
	four	**five**	**six**	**seven**	**eight**	**nine**
household 'type'	'small'		'average'		'large'	
	ANNUAL CEREAL REQUIREMENT PER HOUSEHOLD (kg)*					
	1200	1500	1800	2100	2400	2700
AREA YIELD (kg/ha)	**REQUIRED LAND PER HOUSEHOLD (ha)**					
400	3.00	3.75	4.50	5.25	6.00	6.75
500	2.40	3.00	3.60	4.20	4.80	5.40
600	2.00	2.50	3.00	3.50	4.00	4.50
700	1.71	2.14	2.57	3.00	3.43	3.86
800	**1.50**	**1.88**	**2.25**	**2.63**	**3.00**	**3.38**
900	1.33	1.67	2.00	2.33	2.67	3.00
1000	**1.20**	**1.50**	**1.80**	**2.10**	**2.40**	**2.70**
1100	1.09	1.36	1.64	1.91	2.18	2.45
1200	1.00	1.25	1.50	1.75	2.00	2.25
1300	0.92	1.15	1.38	1.62	1.85	2.08
1400	0.86	1.07	1.29	1.50	1.71	1.93
1500	**0.80**	**1.00**	**1.20**	**1.40**	**1.60**	**1.80**
1600	0.75	0.94	1.13	1.31	1.50	1.69
1700	0.71	0.88	1.06	1.24	1.41	1.59
1800	0.67	0.83	1.00	1.17	1.33	1.50
1900	0.63	0.79	0.95	1.11	1.26	1.42
2000	**0.60**	**0.75**	**0.90**	**1.05**	**1.20**	**1.35**

* if 300 kg of cereals required per year per person

Table 7.10 The required arable land at Çatalhöyük for households of various sizes and for a range of cereal yields

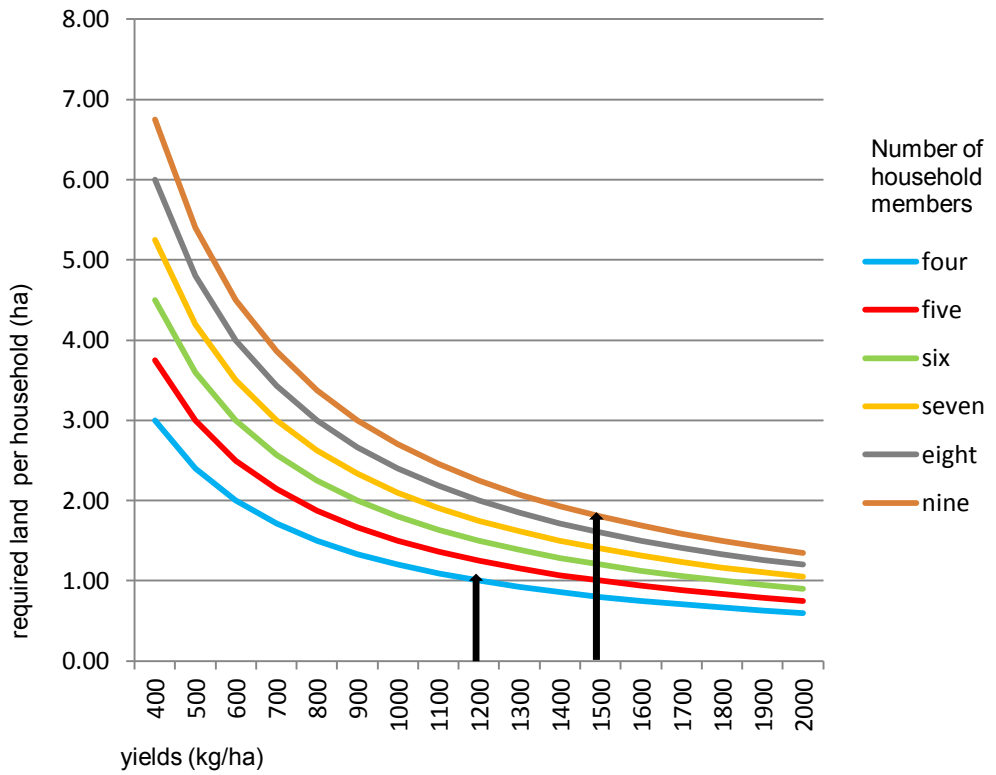


Figure 7.6 The arable land requirement for households of different sizes

The ethnographically recorded intensively cultivated gardens on the island of Evvia, Greece range in size from 6 m^2 to 100 m^2 (Jones *et al*. 1999: Table 2); both minimum and maximum areas refer to 'allotment gardens' - plots located a few minutes' walk from the owners' house (up to 100 m away). 'Back gardens' immediately adjacent to the house are not considered relevant to the agglomerated configuration of Çatalhöyük. Less intensively cultivated plots (including 'fenced fields' and 'vineyards') occupy variable, mostly larger areas than gardens (*c*. 60-700 m^2, with two of the recorded plots of 1200 m^2 and 2250 m^2 area) and are located somewhat farther from the village (e.g. 50-2500 m), whereas 'unfenced fields', subject to stubble or fallow grazing, are generally larger and more distant (e.g. up to 1500 m^2 and as far as 3900 m away from the village) (Jones *et al*. 1999: 176, Table 2). The area of ethnographically documented intensively cultivated plots in Asturias does not exceed 800 m^2 (0.08 ha; Charles *et al*. 2002: 134). The size of the fields in Romania varied from 1 to 100 ares (i.e. 100 m^2-1 ha; 1 are = 100 m^2) and they were located no more than half an hour walking distance from the house; hand-cultivated plots were of 100-200 m^2 in area (Hajnalová and Dreslerová 2009). In Slovakia, individual cereal plots fluctuate between 17 and 40 ares (1700-4000 m^2) and from 30 ares (3000 m^2) to 1 ha (Hajnalová and Dreslerová 2009). While it is plausible that a single small-scale farming household could cultivate multiple plots, it is perceived unlikely that the total cultivated land per household would extend beyond 1 ha given that, in the ethnographic examples, area of gardens which potentially 'supplement' fields is relatively small (for instance, *c*. 15-24 m^2 in Asturias - Charles *et al*. 2002) and, more importantly, taking into account the high cultivation intensity/high amount of the invested labour (Halstead 1995).

If a hectare of arable land is assumed as a maximum 'standard' area hand-cultivated by a Çatalhöyük household, then, as shown in Table 7.10 and Figure 7.6, the area is expected to have yielded from 1200 kg/ha to 2000 kg/ha to satisfy the needs of 'small' and 'average' household (4-5 and 6-7 members respectively), and above 2000 kg/ha for 'large' household (8-9 members). The yield figures are comparable to those experimentally generated for long-term manured and some unmanured crop fields, as well as the ethnographic observations in Asturias (see above).

If each household cultivated more or less the same total area (e.g. 1 ha), then the disparity in the levels of invested labour between, for instance, small and large households would have been great (since lower yields would have been sufficient for smaller households) though

perhaps to some extent compensated by the available workforce in large households. The intensive cultivation proposed for early-mid Neolithic Çatalhöyük implies high yields as a 'standard' for both small and average/large households. Based on the amount of labour required in the intensive cultivation system, it could perhaps be suggested that the distribution of land among the households was uneven in terms of area, i.e. that smaller households cultivated smaller plots of land etc (see Table 7.10). Besides low demands in terms of the plot size, high yields achieved by intensive cultivation practices would have also minimised the distance from the settlement to the crop fields. Some form of communally organised land ownership and/or land use-rights could perhaps be inferred which would have introduced a balance between the size of the household, the land area, the required labour and the available workforce (cf. Bogaard and Isaakidou 2010). Also, the possibility of farming in groups larger than the household should not be excluded.

7.3.8 **Conclusions**

The ecological profile of arable weeds presented in the previous sections suggests that intensive cultivation of permanent autumn-sown fields was practised during the early-mid stages in the Çatalhöyük occupation. In terms of permanence (shifting *vs*. fixed-plot cultivation), the dominance of annuals and extreme rarity of woodland (and steppe) perennials excludes the possibility of frequent clearance of woodland (or steppe) for opening up of new, short-lived fields, where measures applied result in very low to no soil disturbance. Functional ecological comparison of the weed dataset with relevant data from a modern cultivation intensity study in Evvia, Greece showed that Çatalhöyük plots more closely resemble intensively cultivated 'gardens' than extensively cultivated 'fields'. Sowing time was assessed on the basis of the onset and length of flowering period as an indicator of germination time (autumn or spring) and the evidence was somewhat ambiguous; however, in combination with the information on intensity of cultivation, it can be suggested that intensive autumn-sowing was practised.

The intensive nature of cultivation implies that adequate arable land existed close to the site, over an extended annual period (autumn-summer) and throughout a reasonable number of years (i.e. decades) (Halstead 1987, 2006; Jones *et al*. 1999; Bogaard 2004a). It further implies high-labour maintenance of restricted cultivation areas, using techniques such as manual tilling, weeding, and perhaps rotation of cereals and pulses in the same plot in order to

ensure replenishment of nutrients to the soil (Halstead 1987, 2000; Palmer 1998b). Moreover, manuring/middening could have played a major role in enhancing and maintaining soil fertility and tractability (ease of soil working); grazing of stubble (and/or young winter crops - Bogaard *et al*. 2005b) by sheep/(goat) would have provided regular manuring of the plots, while accumulated dung from penned animals could have been spread as fertiliser, in addition to its widespread use as fuel. Strategic use of arable land for livestock pasture, as a supplement to wetland grazing areas, is consistent with integrated crop and animal husbandry at Neolithic Çatalhöyük.

Chapter 8 Conclusions: Plant use, crop husbandry and animal diet at early-mid Neolithic Çatalhöyük

The overall aim of this archaeobotanical project was to advance the understanding of certain key aspects of human-plant relationships during the early-mid Neolithic occupation of Çatalhöyük (*c.* 7400-6600/6500 cal. BC). A series of archaeobotanical and statistical analysis were conducted and the results combined with relevant ethnographic, ecological and biological information. This final chapter provides a summary of the research process and its outcomes, and highlights major conclusions in relation to the principal objectives of the study; the results from Çatalhöyük are examined within the regional context (Section 8.1). It then discusses the social significance of crop and animal husbandry practices and, more broadly, the socio-economic status of agriculture at Çatalhöyük (Section 8.2).

8.1 Addressing the research questions

8.1.1 Food or fuel? Taphonomic considerations

The first main goal of the study was to disentangle the effects on the assemblage of two main taphonomic factors: crop processing and the use of animal dung as fuel. The majority of archaeobotanical samples selected for the analysis based on the archaeobotanical and archaeological criteria are dominated by hulled wheat remains, chiefly glume bases. Though hulled wheat chaff may be over-represented in the assemblage due to piecemeal processing of material stored as spikelets, the abundance and frequency of hulled wheat *grain* compared to the grain/seed of other crop types (free-threshing cereals and legumes) in the samples suggests that hulled wheats were the most important in crop production (Section 4.3). The conclusions drawn from the analysis of samples dominated by hulled wheats are therefore understood as reflecting the status of crop husbandry in general.

The crop processing analysis showed that the majority of samples are by-products of post-dehusking fine sieving and/or winnowing, while a few samples could represent stored semi-cleaned product (hulled wheat spikelets). Overall, therefore, crop material mostly derives from late cleaning stages applied to stores of semi-clean grain.

The samples not dominated by hulled wheats contain very little crop material, and the extremely high abundances of certain wild taxa suggest an alternative, non-crop processing 'mode of arrival'. A certain number of samples are almost entirely composed of the seeds of an oil-rich, small-seeded crucifer - flixweed/wild mustard (*Descurainia sophia*) - which was clearly a collected and stored wild resource, as already proposed in previous work (Fairbairn *et al*. 2005a, 2007; Bogaard *et al*. 2005a, 2009). In addition to *Descurainia*, a range of fruit and nut taxa found in the samples likely represent gathered wild plant food (e.g. almond, acorn, hackberry, pistachio/terebinth, wild plum/sloe).

Another group of samples is dominated by taxa recognised as dung-derived. Seeds of some wild taxa were observed in association with animal (sheep/goat) dung in some of the samples, and complete or fragmented pellets were also noted, supporting the inference that burning of animal dung as fuel is another major activity contributing to the assemblage (Asouti and Fairbairn 2002; Fairbairn *et al*. 2002, 2005a; Bogaard *et al*. 2005a, in press/2013; Matthews 2005a, 2005b, 2010; Rosen 2005). The application of four criteria proposed by Charles (1998) for recognition of dung-derived material in macro-botanical assemblages clearly identified certain wild taxa as arriving on site through sheep/(goat) dung, while others were ecologically and biologically similar and could also have originated in dung. The correspondence analysis plausibly differentiated between arable weeds and dung-derived wild plant material in the samples.

8.1.2 **The nature and scale of crop cultivation**

The second main objective of the project was investigation of the nature and scale of crop husbandry and the relationship between crop cultivation and animal (sheep) herding. The arable weed assemblage was used to explore different aspects of crop husbandry based on the ecological and biological characteristics of the taxa. The results strongly suggest that farmers at early-mid Neolithic Çatalhöyük practised intensive cultivation of crops sown in autumn on long-lived plots located close to the settlement. The high labour-intensity of the management further indicates that cultivation was restricted in scale. The virtual lack of straw (from both the macro-botanical and phytolith records) suggests that harvesting was carried out relatively high on the stem and that straw was left in the fields, perhaps to be grazed by animals (sheep/goat), which would in turn provide fresh manure to maintain high fertility levels of the soil.

8.1.3 **Animal (sheep/goat) diet and the use of dung**

Plant remains that arrived at the site via animal dung provide a basis for consideration of livestock diet which, based on the composition of the dung-derived assemblage, was highly varied, reflecting a diversity of vegetation and habitat types (dry and wet, arable and non-arable) around the site. These data support the suggestion, stemming from microwear analysis of sheep molars, that local animal food sources would have offered a variety of choice and high nutritional levels (Henton 2012). Consideration of the biology and ecology of dung-derived taxa allowed inferences on the seasonality, method and location of animal feeding. It is proposed that grazing was the general method of consumption and that it could have been practised from mid-spring until late autumn. Animals kept within the site (in pens) e.g. over winter could have been fed fodder containing local wetland plants (sedges, rushes, grasses) and crop processing by-products.

Animal dung was used for fuel and perhaps also to manure cultivation plots; ethnographic examples show that the two suggested uses of dung are not incompatible (e.g. Ertuğ-Yaraş 1997: 364) and on- and off-site dung deposits (e.g. in pens) would have been concentrated source for both, while grazing animals would have deposited dung directly on fields when folded on arable land.

In sum, the archaeobotanical evidence points to intensive cultivation of crops and implies a certain functional integration of crop and animal husbandry, where cultivation areas provide grazing (and fodder in the form of crop processing by-products) for some livestock at certain times of year (cf. Halstead 1987, 1996, 2006).

8.1.4 **The plant assemblage from Çatalhöyük in its regional context**

Consideration of the broader ramifications of the results from Çatalhöyük is inevitably constrained by the variable level of archaeobotanical analysis conducted at the sites in the Konya plain and beyond, as well as by the differences in the preservation of the material. Nonetheless, published data from several sites in Central Anatolia (see Section 2.2.3) that pre-date, or are contemporary with Çatalhöyük allow for some general observations on the extent

to which the patterns recognised within this study may apply to the other archaeobotanical assemblages.

A uniform, and relatively wide, spectrum of crop types is characteristic of the Neolithic sites in Central Anatolia (see Asouti and Fairbairn 2002: Table 1), indicating that crop cultivation was a major subsistence practice, and that both cereals and pulses were major constituents of the diet in the region (and beyond - see e.g. Lösch *et al*. 2006). The presence of cereal chaff (mainly of hulled wheats) demonstrates on-site crop processing activities. *In situ* preserved crop stores, comparable to those discovered at Çatalhöyük (Helbaek 1964; Fairbairn *et al*. 2005; Bogaard *et al*. 2005a, 2009) have not been reported for other Anatolian sites. An exception could be deposits from lower levels at Erbaba where relatively large concentrations of charred emmer grain, free-threshing wheat, pea and bitter vetch were recorded (van Zeist and Buitenhuis 1983: Tables 1-2). A number of fruit and nut taxa are regularly present in the assemblages from Central Anatolia (most prominently hackberry, pistachio and almond) perhaps testifying a significant dietary role of these gathered sources.

While the plant food basis documented at Çatalhöyük can be understood as representative of the wider pattern so far observed in Central Anatolia, some (local) preferences for one or the other crop, or differences in crop processing activities among the sites have been noted. For example, a large quantity of bitter vetch seeds recovered at Aşıklı Höyük (and further to the south-east, at aceramic Çayönü) has been interpreted as potentially showing a greater importance of the taxon as the likely human food compared to other identified pulses (van Zeist and de Roller 1991/1992, 1995: 183). Interestingly, at the site of Erbaba, fruit and nut taxa are apparently lacking (van Zeist and Buitenhuis 1983: 56) perhaps due to their genuine absence from the surroundings of the site in the Neolithic (Asouti and Fairbairn 2002: footnote 9). At Aşıklı Höyük, by-products of processing of free-threshing cereals (rachis internodes, and perhaps culm nodes) outnumber grain, which was seen as an indicator of the practice of bringing the whole plants to the site for subsequent processing. Further, the presence of culm bases and culm nodes, and the overall dearth in potential weed seeds at the site were understood as reflecting the method of harvesting by uprooting (van Zeist and de Roller 1995: 184). By comparison, crop processing analysis of the Çatalhöyük assemblage revealed presence of by-products of *late* stages in crop cleaning (winnowing/fine sieving); no definite cereal culm nodes or culm bases were identified. The consideration of crop harvesting

method indicated sickle-harvesting at a medium height of the straw as the commonly applied technique at Çatalhöyük.

In the wild/weed record from the Anatolian sites, a similar set of taxa from dryland and wetland, natural and/or anthropogenic habitats were identified, and they are, in contrast to those recovered at Çatalhöyük, generally assumed to have arrived with the harvested crops (i.e. as arable weeds) (van Zeist and Buitenhuis 1983:63; van Zeist and de Roller 1995). However, based on the clear association of wetland taxa with animal (sheep) dung at Çatalhöyük, it is perhaps plausible that at least some of these taxa (e.g. sedges) are also dung-derived at other Central Anatolian Neolithic sites. Clearly, the type and extent of the available grazed and/or foddered vegetation would have varied depending on the environmental conditions, but the location of the sites near rivers, lakes or marshy areas suggests the presence of wet habitats nearby, as reflected in the botanical assemblages. Also, small-seeded grasses and legumes, and some other dryland taxa such as *Ziziphora*, *Helitropium* and *Helianthemum* could have the same origin in the samples, as well as (some) taxa occurring in arable and ruderal areas. As indicated in Table 2.3, herding of sheep/goat has been documented in the faunal record from the majority of these sites. Moreover, micromorphological analysis at Aşıklı Höyük showed evidence of burnt and unburnt dung resembling possible stabling deposits at Çatalhöyük (Matthews 1998: Appendix 2). Also, in the soil samples from aceramic Çayönü further to the east, spherulites from dung were discovered and identified as deriving from small ruminants kept within or near the settlement (Brochier 1993). In addition, the macro-botanical analysis at Çayönü have revealed occurrence of the set of wild/weed taxa comparable to the dung-derived assemblage at Çatalhöyük (van Zeist and de Roller 1991/1992: Table 3). It seems likely that sheep/goat dung was used as fuel in Central Anatolia and beyond during the Neolithic, leaving the specific 'signature' in the charred botanical assemblages.

The collection and use of sheep/goat dung and, more directly, the documented presence of wild/managed and, in particular, (fully) domesticated caprines suggest close control of small herds tended in the settlements' vicinity, rather than the existence of large herds across a wide terrain and regularly interbreeding with wild sheep and goat (cf. Bogaard 2005). The intensive management of livestock would have been compatible with the small-scale intensive agriculture proposed for Çatalhöyük. However, due to the likely contribution of dung-derived plant material to the 'weed' assemblages, detailed consideration and understanding of the

taphonomic complexity, for which this study can provide guidelines, is required before making any inferences on the scale and nature of agriculture at other Central Anatolian Neolithic sites.

8.2 The socio-economic role of integrated mixed farming at Çatalhöyük

Intensive cultivation demands high inputs of labour and considerable time committed to maintenance of crops through tillage, manual weeding, regular manuring and perhaps practices such as cereal-pulse rotation and sowing by dibbling or row-sowing (as opposed to less intensive broadcasting). As a consequence (and a requirement), intensively cultivated areas are located near to the settlement and are modest in scale – some plots may be 'garden-like'. They provide high yields per unit area. Furthermore, such a regime allows for a certain level of integration of plant and animal (sheep) husbandry, where sheep are allowed to graze unripe crops and regulate their growth (e.g. promote tillering, prevent lodging), and/or are put on stubble for grazing and direct manuring (Halstead 1987, 1989, 2000, 2006; Jones *et al*. 1999; Charles *et al*. 2002; Bogaard 2004a, 2004b: Table 2, 2005; Jones 2005). This model of land use resembles activities of recent small-scale subsistence farmers of the Mediterranean who cultivate small plots of land and raise small number of livestock sufficient for domestic (household) consumption (Halstead 1987, 1989, 2000). They practice 'diversified farming' by growing a range of crops (and livestock) in order to maximise the use of land and the available labour, and to minimise the risk of subsistence failure (Halstead 1996, 2000).

Based on archaeological, environmental and ethnographic data, intensive small-scale crop and animal husbandry has been proposed as a (dominant) subsistence strategy for Neolithic communities in Greece (Halstead 1987, 1989, 1996, 2000, 2006; cf. Jones *et al*. 1999; Valamoti 2004). Furthermore, an intensive cultivation model has been archaeobotanically demonstrated for the Neolithic *Linearbandkeramik* culture of central Europe and has been inferred for the early Neolithic Körös sites in the Great Hungarian Plain and the Teleorman valley in south-central Romania, based on the faunal and botanical evidence respectively (Bogaard 2004a, 2004b, 2005, 2012; Bogaard *et al*. 2007). The annual weeds potentially indicative of intensive small-scale cultivation (e.g. *Chenopodium album* - fat hen, *Solanum nigrum* - black nightshade, *Polygonum convolvulus* - black bindweed; Bogaard 2004b) also

occur in the assemblages from Neolithic sites in other regions of Europe (e.g. Colledge and Conolly 2007). Apparently, small-scale intensive cultivation was a widespread practice across early Neolithic Europe.

The successful application of small-scale intensive cultivation across geographic regions and time-periods lies in its 'artificial' character, where high soil fertility levels resulting in high yields per unit area (compared to extensively cultivated fields) are *created* by intensive cultivation practices and do not represent natural growing conditions - they remain, to a large extent, unaffected by variable environments. The labour requirements of the intensive cultivation are high but are alleviated by its integration with livestock herding of comparable/viable scale and intensity. Functional interdependence between small-scale crop and animal husbandry is at the core of the intensive mixed farming regime and holds a key to its continuity and stability (Halstead 1989, 1996, 2000; Bogaard 2004a, 2004b, 2005).

The possibility of emergence of the integrated husbandry regime in the Near East and its continuity and transfer into Europe has been previously noted (Bogaard 2005; Bogaard and Isaakidou 2010; cf. Colledge 2001). Direct evidence pointing to the nature of crop cultivation - arable weeds accompanying crops - was however obscured by the complex taphonomy of archaeobotanical assemblages from south-west Asia due to the likely widespread burning of dung as domestic fuel (Miller 1984, 1996; Charles 1998; Bogaard and Charles 2010). The identification of arable weeds at Çatalhöyük offers a major opportunity to investigate aspects of food production system at the site such as the scale and nature, productivity and long-term sustainability, the extent and availability of arable land and, beyond subsistence, the social significance of crop cultivation.

At early-mid Neolithic Çatalhöyük crops were sown in autumn, on fixed/long-established intensively cultivated plots. Autumn-sowing is a plausible sowing regime for the crop types identified (and perhaps the only viable for early cereal domesticates - Hillman and Davies 1992; H. Jones *et al*. 2009). The permanence of plots may signify that application of intensive methods on the same patches of land over an extended period of time had been necessary in order to create rich garden soil (Jones 2005), but it also implies continuous availability and productivity of the cultivated land and suggests constancy and reliability of the agricultural system. Intensive cultivation entails small-scale plots located close to habitation (Jones *et al*. 1999; Jones 2005). The close proximity of plots to the settlement at Çatalhöyük would have

facilitated regular day-to-day care of crops including repeated hoeing and weeding. Some plots would also be near overnight sheep/goat penning areas (kept near the site to protect animals from predators), facilitating transport of manure from pens to arable land. Fencing of sheep/goat on arable plots could have been practised at certain points in the agricultural schedule (e.g. to graze stubble).

Ethnographic examples of intensive cultivation suggest that it is ideally suited to settlements with a dispersed pattern, where land immediately around and between houses (i.e. close to homes) is cultivated (e.g. Jones *et al*. 1999; Jones 2005). The large size of the settlement at Çatalhöyük implies that distances to some cultivation plots would reduce the intensity of management. Nonetheless, while manure and midden material would tend to be deposited close to the settlement, grazing sheep could be used as a mobile source of manure for more distant areas (Bogaard and Isaakidou 2010). Also, potential areas of higher, regularly flooded well drained land (e.g. levees) may not have been in need of manuring to sustain long-term crop cultivation (Cappers and Raemaekers 2008: 390).

The intensity of cultivation at Çatalhöyük thus implies some integration of crop and animal husbandry. The arable and dung-derived botanical evidence indicate that the patchwork of landscape forms and vegetation types in the vicinity of the settlement would have provided a favourable environment for tending of both crops and sheep/goat. It is possible that parts of the herd (e.g. breeding females, non-productive animals) were run on different pastures and some certainly outside arable land *per se* (though this would have placed additional stress on labour-investing household - Halstead 1996) but again within short distances from the settlement, most likely on the surrounding lowlands (Henton 2010, 2012). There seems to have been enough quality pasture near the settlement without continual reliance on crop field and field-edge weeds and ruderals, and the maintenance of the natural sheep breeding cycle (i.e. late spring births) limited grazing on early spring crops to fallow herds (Henton 2012). The presence of cereal stubble indicators in the dung assemblage shows that this was probably an important/complementary source of late summer graze before the autumn culling period, while crop (by-)products could have been an (additional) fodder supply (Henton 2010, 2012, in press/2013).

The limited area of worked land inferred from the intensive high-input cultivation practices could have provided for the subsistence of a small farming family/household (Halstead 1987,

1989, 1995). The small scale of off-site crop management is compatible with on-site evidence for storage, processing (and consumption) of plant food at Çatalhöyük (Bogaard *et al*. 2009; Twiss *et al*. 2009) suggesting an overall household-based character of crop cultivation in the early-mid occupation phases. The 'household-oriented' nature of crop husbandry lends support to the suggested autonomy of household as the fundamental constituent and an independent socio-economic unit of early farming communities of south-west Asia, previously inferred from e.g. elements of domestic architecture and food preparation and consumption inventory (Flannery 1972, 2002; Byrd 1994, 2000; Kuijt 2000; Wright 2000; Banning 2003). The emergence of the household as an isolated unit of production and consumption is seen as consequential and highly advantageous in food-producing economies where labour-investments are high; small-scale production within and for families improves the system efficiency, allowing for better recruitment and organisation of available workforce and enables transparency in food production, storage and consumption (Flannery 1972, 2002). The concealed/private nature of household storage and domestic scale of plant consumption at Çatalhöyük may be envisaged as linked to the general 'privacy' in plant production, though outdoor and off-site plant-related activities would have been much more visible/public and would have likely involved inter-household social contact and cooperation (Fairbairn *et al*. 2005a; Ertuğ 2000) perhaps on the neighbourhood level (Düring and Marciniak 2006; Marciniak 2008).

The small-scale farming and household-level production appears to have been an economically viable and highly resilient subsistence strategy over a long period of the early-mid Neolithic occupation at Çatalhöyük. The balance between arable and pastoral activities and the amounts of produced food likely varied among the households depending on the available labour power and land area, the actual intensity of cultivation of individual plots, 'external' factors such as favourable weather conditions and so on (Sahlins 1974). Diversified mechanisms could have been in place for buffering low yields, and shifting emphasis on one or the other aspect of the mixed economy may have been one of the strategies. Indirect 'storage' of surplus grain by feeding it to animals, distribution of surplus beyond the household, exchange of products and diversification of resources are some possible ways of overcoming the times of need (e.g. Leatherman *et al*. 1989; Halstead and O'Shea 1989; Halstead 1995). The demonstrated extra-household sharing of meat (mostly cattle) as opposed to the 'hoarding' of plant foodstuffs at Çatalhöyük (Bogaard *et al*. 2009; Twiss *et al*. 2009)

could have had a role in supporting households affected by low food availability indicating reliance on social support networks beyond the household.

Besides its potential role in coping with food shortages, livestock seem to have played an important part in maintaining good relationships between neighbours in general; the sharing of meat seem to have been crucial in conserving social ties and enhancing communal cohesion (Bogaard *et al*. 2009; Twiss *et al*. 2009; cf. Halstead 2012). The intensive nature of household farming could have led to differentiation between the households based on e.g. their manpower and production potential, and could have included rising tensions over land tenure and competition for most valuable plots such as those located closest to the settlement ('infield plots' - Jones 2005; Bogaard and Isaakidou 2010). The labour-demanding character of intensive agriculture may have resulted in appropriation of land by farming families or groups; investment of time and energy in production and maintenance of rich garden soil would likely result in close relationship with the land including the effort to retain the same patch of highly valued land over prolonged time and through multiple generations (Ingold 1996; Jones 2005). Self-contained residential units and secluded plant storage areas could be understood as reflecting the appropriation/control by the household of the cultivated land and the products obtained, though some form of communal land tenure and regulated allocation of cultivation plots among the households could have been possible, or even necessary for community to last long-term (Bogaard and Isaakidou 2010). Land tenure (as any 'material holding') would have had a social dimension expressed in social relations (Ingold 1996). In the context of a large aggregated settlement where subsistence security must have been an ever-present challenge, the development of economic inequalities and exertion of claims over resources would have strained social cohesion and could have led to intra-communal divisions and social conflict (Bogaard and Isaakidou 2010). To this end, Çatalhöyük (and other 'megasites') would have not survived for very long without strong social pressures and effective modes of reaching and enforcing decisions and norms towards organisation of the community and prevention of household differentiation that would lead to the collapse (Halstead 1995; Cutting 2005; Bogaard and Isaakidou 2010). One of the 'levelling mechanisms' (Halstead 1995) may have been a formalised balance between the small-scale intensive nature of plant food production, processing and consumption, and sharing of meat beyond the household.

In addition to the social mechanisms, ritual/symbolic practices may have been an important component of the processes that brought and kept the people together, and that balanced the 'disadvantages' of the economic intensity and high labour demands with the benefits of sedentary life in a densely populated village (Hodder and Cessford 2004; Hodder 2007). At Çatalhöyük, and other Neolithic settlements in Anatolia (and beyond), it appears that a strong bond between people and place developed, perhaps based on memory and history. This is particularly visible in the repetitive practices in house construction at Çatalhöyük: continuous rebuilding of the house through its life (e.g. replastering of walls, floors and reliefs), placing new houses in the same location, i.e. on top of old ones, while often retaining the same internal organisation of space, and replication of the art and symbolism of the previous structure. Moreover, there is evidence that earlier symbolic objects (e.g. sculptures, bucrania) were retrieved and re-used in later houses (Cutting 2005; Hodder and Cessford 2004; Düring 2006; Hodder 2006, 2007). The level of investment into the 'construction of long-term memory' may have varied between houses/households, as indicated by presence of structures that contain relatively large number of burials (e.g. 62 in Buidling 1 - Andrews *et al*. 2005) and/or more elaborate art (e.g. Building 44), and were rebuilt through multiple building phases; they have been described as 'dominant'/'history'/'ancestral' houses and may have been particularly concerned with preservation and control of a collective memory (Hodder and Cessford 2004; Hodder 2006, 2007). The on-site repetitive practices were likely paralleled in the regular and repeated off-site activities, including agricultural production. The continuous tending of fields throughout the year, the high energy and time investment, and the established seasonal round of activities involved in crop growing and plant use may have had their share in the maintenance of both individual and collective memory. Tied to a specific plot of land, the memory may have served as a(nother) medium for regulating land rights but also imposing a sense of duty and responsibility to the farming household. It is difficult to see the potential role of 'history' houses in the continuity of arable production as evidenced by the present study and noted in the previous and ongoing archaeobotanical analysis (Fairbairn *et al*. 2005; Bogaard *et al*. in press/2013). The archaeobotanical content of the *in situ* burnt, and thus highly informative Building 1 does not differ, in terms of taxonomic diversity, from the assemblages recovered from the unburnt structures. The potentially 'special' status of this and other history houses does not seem to have had an effect on the range of cultivated crops and the nature of production as recognised in the archaeobotanical record; a possible link, however, between the building/household status and the configuration (size and location) of arable plots in the wider landscape cannot be excluded. Overall, the intensive mode of

cultivation seems to have been a norm across space and time, maintaining the economic and symbolic continuity between households and generations.

Successfully combined within the intensive food production system at the household level, closely intertwined crop and animal husbandry at Çatalhöyük likely contributed to the development and longevity of the site in different ways, and may have shaped the community in different (contrasting) directions. The integration of the two aspects of economy, supported by social practices promoting an egalitarian ethos (Kuijt 2000) such as intra-communal sharing, hospitality and solidarity, would have reduced the risks of economic failure and counteracted the development of economic and social inequality over the long term. It could thus be argued that the social constraints and opportunities posed by agriculture were as crucial to Çatalhöyük's extraordinary stability and duration as the subsistence base it offered.

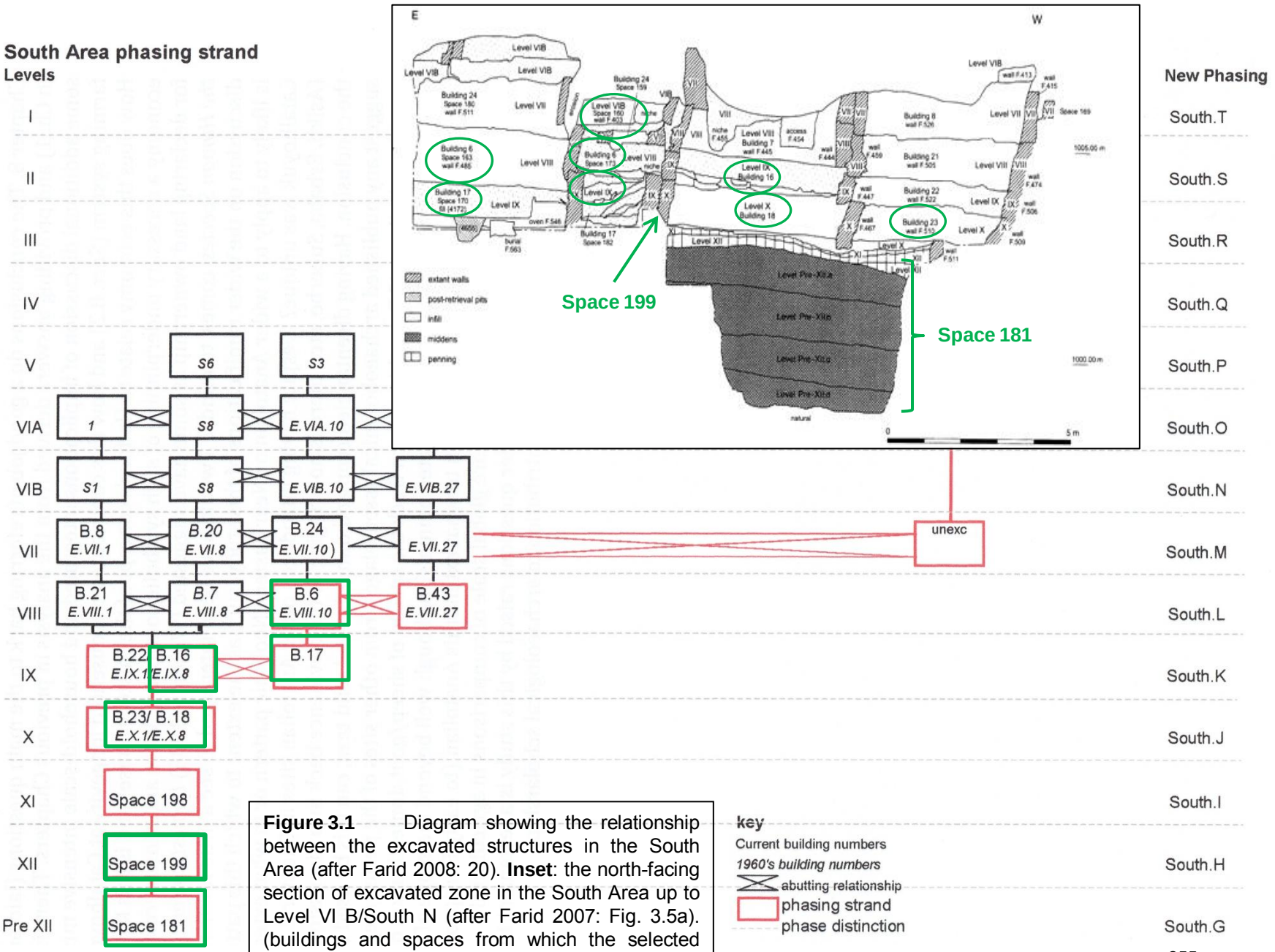


Figure 3.1 Diagram showing the relationship between the excavated structures in the South Area (after Farid 2008: 20). **Inset**: the north-facing section of excavated zone in the South Area up to Level VI B/South N (after Farid 2007: Fig. 3.5a). (buildings and spaces from which the selected samples derive are marked green)

	Sample number	Final crop counts (multiplied)	Final wild taxa counts (multiplied)	All items count	% Crop	% Wild	General classification, 70% cut-off	General classification, 60% cut-off
1	144	43754	327	44081	99.26	0.74	crop-rich	crop-rich
2	4714	2729	39	2768	98.59	1.41	crop-rich	crop-rich
3	1804	1534	42	1576	97.34	2.66	crop-rich	crop-rich
4	173	1601	62	1663	96.27	3.73	crop-rich	crop-rich
5	192	633	32	665	95.19	4.81	crop-rich	crop-rich
6	281	926	54	980	94.49	5.51	crop-rich	crop-rich
7	3499	428	37	465	92.04	7.96	crop-rich	crop-rich
8	232	497	45	542	91.70	8.30	crop-rich	crop-rich
9	904	1145	109	1254	91.31	8.69	crop-rich	crop-rich
10	295	1500	153	1653	90.74	9.26	crop-rich	crop-rich
11	1669	776	86	862	90.02	9.98	crop-rich	crop-rich
12	4741	939	106	1045	89.86	10.14	crop-rich	crop-rich
13	1791	572	69	641	89.24	10.76	crop-rich	crop-rich
14	813	490	62	552	88.77	11.23	crop-rich	crop-rich
15	677	1176	156	1332	88.29	11.71	crop-rich	crop-rich
16	4545.4626	2347	313	2660	88.23	11.77	crop-rich	crop-rich
17	1735	659	88	747	88.22	11.78	crop-rich	crop-rich
18	1038	701	105	806	86.97	13.03	crop-rich	crop-rich
19	539.551	1221	186	1407	86.78	13.22	crop-rich	crop-rich
20	1217	168	27	195	86.15	13.85	crop-rich	crop-rich
21	2439	291	51	342	85.09	14.91	crop-rich	crop-rich
22	1950	711	129	840	84.64	15.36	crop-rich	crop-rich
23	3099	528	99	627	84.21	15.79	crop-rich	crop-rich
24	940	605	118	723	83.68	16.32	crop-rich	crop-rich
25	588	702	145	847	82.88	17.12	crop-rich	crop-rich
26	3338	305	65	370	82.43	17.57	crop-rich	crop-rich
27	2236	243	52	295	82.37	17.63	crop-rich	crop-rich
28	639	770	175	945	81.48	18.52	crop-rich	crop-rich
29	31-48.49.51	2212	513	2725	81.17	18.83	crop-rich	crop-rich
30	2474	130	32	162	80.25	19.75	crop-rich	crop-rich
31	2763	190	47	237	80.17	19.83	crop-rich	crop-rich
32	3026	447	111	558	80.11	19.89	crop-rich	crop-rich
33	2576	184	47	231	79.65	20.35	crop-rich	crop-rich
34	4732	675	179	854	79.04	20.96	crop-rich	crop-rich
35	1795	787	209	996	79.02	20.98	crop-rich	crop-rich
36	830	319	85	404	78.96	21.04	crop-rich	crop-rich
37	2425	351	94	445	78.88	21.12	crop-rich	crop-rich
38	674	541	145	686	78.86	21.14	crop-rich	crop-rich
39	345	188	53	241	78.01	21.99	crop-rich	crop-rich
40	1631	324	93	417	77.70	22.30	crop-rich	crop-rich
41	3399	1160	366	1526	76.02	23.98	crop-rich	crop-rich
42	26-25.36	339	107	446	76.01	23.99	crop-rich	crop-rich
43	2679	153	49	202	75.74	24.26	crop-rich	crop-rich
44	5030	395	127	522	75.67	24.33	crop-rich	crop-rich
45	198	447	149	596	75.00	25.00	crop-rich	crop-rich
46	1010	398	138	536	74.25	25.75	crop-rich	crop-rich
47	1853	340	118	458	74.24	25.76	crop-rich	crop-rich
48	513	453	159	612	74.02	25.98	crop-rich	crop-rich
49	1156	248	89	337	73.59	26.41	crop-rich	crop-rich
50	1297.164	1361	489	1850	73.57	26.43	crop-rich	crop-rich
51	27-13.15	783	286	1069	73.25	26.75	crop-rich	crop-rich
52	2792	203	77	280	72.50	27.50	crop-rich	crop-rich
53	16-31.49.64.1732	2348	906	3254	72.16	27.84	crop-rich	crop-rich
54	25-94.95.96	684	270	954	71.70	28.30	crop-rich	crop-rich
55	2985	266	105	371	71.70	28.30	crop-rich	crop-rich
56	26-37.38	329	134	463	71.06	28.94	crop-rich	crop-rich

Table 4.1 Absolute and percentual representation of crop and wild material in the samples

57	128	537	230	767	70.01	29.99	crop-rich	crop-rich
58	366	511	220	731	69.90	30.10	crop-rich	crop-rich
59	2535	307	139	446	68.83	31.17	*mixed*	crop-rich
60	1579	485	226	711	68.21	31.79	*mixed*	crop-rich
61	5176	240	112	352	68.18	31.82	*mixed*	crop-rich
62	31-04.06.07	1129	564	1693	66.69	33.31	*mixed*	crop-rich
63	4361	1101	581	1682	65.46	34.54	*mixed*	crop-rich
64	2661	112	60	172	65.12	34.88	*mixed*	crop-rich
65	2326	153	107	260	58.85	41.15	*mixed*	*mixed*
66	135	204	146	350	58.29	41.71	*mixed*	*mixed*
67	465	720	630	1350	53.33	46.67	*mixed*	*mixed*
68	520	924	817	1741	53.07	46.93	*mixed*	*mixed*
69	171.329	463	416	879	52.67	47.33	*mixed*	*mixed*
70	3546	137	135	272	50.37	49.63	*mixed*	*mixed*
71	395	834	1316	2150	38.79	61.21	*mixed*	wild-rich
72	3666	912	1498	2410	37.84	62.16	*mixed*	wild-rich
73	3297	875	1570	2445	35.79	64.21	*mixed*	wild-rich
74	31-27.33.37	958	2178	3136	30.55	69.45	*mixed*	wild-rich
75	3247	548	1586	2134	25.68	74.32	wild-rich	wild-rich
76	74.103	289	1120	1409	20.51	79.49	wild-rich	wild-rich
77	78	290	1565	1855	15.63	84.37	wild-rich	wild-rich
78	515	186	1194	1380	13.48	86.52	wild-rich	wild-rich
79	3351	185	1330	1515	12.21	87.79	wild-rich	wild-rich
80	104	338	2730	3068	11.02	88.98	wild-rich	wild-rich
81	535	805	6531	7336	10.97	89.03	wild-rich	wild-rich
82	3742	706	7563	8269	8.54	91.46	wild-rich	wild-rich
83	150	363	4092	4455	8.15	91.85	wild-rich	wild-rich
84	282	313	4105	4418	7.08	92.92	wild-rich	wild-rich
85	23	363	5022	5385	6.74	93.26	wild-rich	wild-rich
86	11	429	8177	8606	4.98	95.02	wild-rich	wild-rich
87	5019	39	847	886	4.40	95.60	wild-rich	wild-rich
88	102	286	8381	8667	3.30	96.70	wild-rich	wild-rich
89	101	73	4208	4281	1.71	98.29	wild-rich	wild-rich
90	45	376	34549	34925	1.08	98.92	wild-rich	wild-rich
91	3324	133	25144	25277	0.53	99.47	wild-rich	wild-rich
92	87	51	14037	14088	0.36	99.64	wild-rich	wild-rich
93	332	108	85392	85500	0.13	99.87	wild-rich	wild-rich
94	516	591	2601107	2601698	0.02	99.98	wild-rich	wild-rich

Table 4.1 - *continued* Absolute and percentual representation of crop and wild material in the samples

Family	TAXA	plant part
Alismataceae	*Alisma* L.	seed, endosperm
Anacardiaceae	*Pistacia terebinthus* L.	drupes
Boraginaceae	*Boraginaceae* , large	seed, silicified
Boraginaceae	*Buglossoides arvensis* L. type	seed, silicified
Boraginaceae	*Heliotropium* L.	seed
Boraginaceae	*Lithospermum officinale* L.	seed, silicified
Campanulacae	*Campanula* L.	seed
Caryophyllaceae	*Caryophyllaceae*	seed
Caryophyllaceae	*Silene* sp.	seed
Caryophyllaceae	*Vaccaria pyramidata* Medik.	seed
Chenopodiaceae	*Atriplex* L.	seed
Chenopodiaceae	*Beta* L.	seed
Chenopodiaceae	*Chenopodiaceae*	endosperm
Chenopodiaceae	*Chenopodium album* L. type	seed
Chenopodiaceae	*Chenopodium chenopodioides* L. type	seed
Chenopodiaceae	*Chenopodium* L.	seed
Chenopodiaceae	*Salsola* L.	seed
Chenopodiaceae	*Suaeda* L.	seed
Cistaceae	*Helianthemum* Adans.	seed
Compositae	*Artemisia annua* L. type	seed
Compositae	*Centaurea* sp.	seed
Compositae	*Compositae* , large	seed
Compositae	*Compositae* , small	seed
Convolvulaceae	*Convolvulus arvensis* L. type	seed
Cruciferae	*Boreava orientalis* Jaub. & Spach	fruit
Cruciferae	*Capsella* Medik.	seed
Cruciferae	*Conringia orientalis* L.	seed
Cruciferae	*Crucifereae* , large	seed
Cruciferae	*Crucifereae* , medium	seed
Cruciferae	*Crucifereae* , round type	seed
Cruciferae	*Descurainia sophia* (L.) Webb	seed
Cyperaceae	*Carex* L.	seed
Cyperaceae	*Cyperaceae*	endosperm
Cyperaceae	*Cyperaceae*	tuber
Cyperaceae	*Cyperaceae* , small	seed
Cyperaceae	*Eleocharis* R. Br.	seed, silicified
Cyperaceae	*Bolboschoenus glaucus* (Lam.) S.G. Smith	seed
Cyperaceae	*Bolboschoenus* sp.	tuber
Dipsacaceae	cf. *Dipsacaceae*	seed
Euphorbiaceae	*Euphorbia* L.	seed
Fagaceae	*Quercus* L.	cotyledons
Geraniaceae	*Erodium* L'Hérit.	seed
Geraniaceae	*Geranium* L., small type	seed
Graminae	*Aeluropus* Trin.	seed
Graminae	*Bromus danthoniae* Trin. type	seed
Graminae	*Crypsis aculeata* (L.) Aiton type	seed
Graminae	cf. *Secale* sp.	seed
Graminae	*Cornucopiae cucullatum* L. type	seed
Graminae	*Eragrostis* N.M. Wolf	seed
Graminae	*Eremopyrum* (Ledeb.) Jaub. & Spach	seed
Graminae	*Graminae* , large	seed
Graminae	*Graminae* , medium	seed
Graminae	*Graminae* , small	seed

Table 4.4 Wild taxa

Family	TAXA	plant part
Graminae	*Hordeum murinum* L. type	seed
Graminae	*Hordeum spontaneum* C. Koch type	seed
Graminae	*Lolium* L./*Hordeum* L.	seed
Graminae	*Phragmites australis* (Cav.) Trin.	stem culm nodes
Graminae	*Sporobolus* R. Br. (S. virginicus (L.) Kunth type)	seed
Graminae	*Stipa* L.	seed
Graminae	*Taeniatherum caput-medusae* L.	rachis
Graminae	*Taeniatherum caput-medusae* L.	seed
Juncaceae	*Juncus* L.	seed
Labiateae	cf. *Lallemantia peltata* L.	seed
Labiateae	*Sideritis* L. type	seed
Labiateae	*Teucrium* L.	seed
Labiateae	*Ziziphora capitata* L./*persica* Bunge	seed
Leguminosae	cf. *Leguminosae*	seed
Leguminosae	*Leguminosae* , small round type	seed
Leguminosae	*Leguminosae* , small wild	seed
Leguminosae	*Vicia* L./*Lathyrus* L.	seed
Lemnaceae	*Lemna* L.	seed, silicified
Linaceae	*Linum* L.	seed
Malvaceae	*Lavatera* L. type	seed
Malvaceae	*Malva* L.	seed
Malvaceae	*Malvaceae*	endosperm
Papaveraceae	*Fumaria* L.	seed
Papaveraceae	*Papaver* L.	seed
Polygonaceae	*Polygonaceae*	seed
Polygonaceae	*Polygonum aviculare* aggregate	seed
Polygonaceae	*Polygonum convolvulus* L.	seed
Polygonaceae	*Rumex* L.	seed
Potamogetonaceae	*Potamogeton* L.	endosperm
Primulaceae	*Anagallis* L.	seed
Primulaceae	*Androsace* L.	seed
Ranunculaceae	*Adonis annua/aestivalis* L.	achenes
Ranunculaceae	*Ranunculus* L.	seed
Rosaceae	*Amygdalus orientalis* L. type	shell, complete and fragmented
Rosaceae	cf. *Potentilla* L. type	seed
Rosaceae	*Prunus divaricata* Ledeb. type	stone fragments
Rosaceae	*Prunus* L./*Amygdalus* L.	stone/shell fragments
Rosaceae	*Prunus spinosa* L. type	stone, complete and fragmented
Rosaceae	*Rosa* L.	seed
Rubiaceae	*Galium aparine* L. type	seed
Rubiaceae	*Galium verum* L. type	seed
Ruscaceae	*Polygonatum* Miller	seed
Solanaceae	cf. *Solanaceae*	seed
Thymeleaceae	*Thymelea passerina* (L.) Cosson & Germ. type	seed
Ulmaceae	*Celtis* L.	nutlets, silicified
Valerianellaceae	*Valerianella* Miller	seed
Verbenaceae	*Verbena officinalis* L.	seed
Violaceae	*Viola* L.	seed
	Chenopodiaceae/Caryophyllaceae	endosperm
	Compositae/Dipsacaceae	seed
	indeterminate nut	nut kernels

Table 4.4 - *continued* Wild taxa

Taxa	GROUP	Number of items	Ubiquity	
			count	%
	FRUIT, NUT, TUBER	**952**	**81**	**86.17**
Amygdalus orientalis L. type	Fruit, nut, tuber	5	5	5.32
Bolboschoenus sp.	Fruit, nut, tuber	79	36	38.30
Celtis L.	Fruit, nut, tuber	503	52	55.32
Cyperaceae	Fruit, nut, tuber	2	1	1.06
Pistacia terebinthus L.	Fruit, nut, tuber	132	44	46.81
Prunus divaricata Ledeb. type	Fruit, nut, tuber	85	18	19.15
Prunus L./*Amygdalus* L.	Fruit, nut, tuber	63	23	24.47
Prunus spinosa L. type	Fruit, nut, tuber	7	4	4.26
Quercus L.	Fruit, nut, tuber	64	24	25.53
Rosa L.	Fruit, nut, tuber	1	1	1.06
indeterminate nut kernels	Fruit, nut, tuber	11	8	8.51
	REED	**173**	**49**	**52.13**
Phragmites australis (Cav.) Trin.	reed	173	49	52.13
	WILD/WEED	**2835790**	**94**	**100.00**
Adonis annua/aestivalis L.	Wild/weed	32	13	13.83
Aeluropus Trin.	Wild/weed	11619	39	41.49
Alisma L.	Wild/weed	17	6	6.38
Anagallis L.	Wild/weed	7	2	2.13
Androsace L.	Wild/weed	39	5	5.32
Artemisia annua L. type	Wild/weed	1724	14	14.89
Atriplex L.	Wild/weed	168	20	21.28
Beta L.	Wild/weed	10	6	6.38
Bolboschoenus glaucus (Lam.) S.G. Smith	Wild/weed	10779	93	98.94
Boreava orientalis Jaub. & Spach	Wild/weed	20	8	8.51
Bromus danthoniae Trin. type	Wild/weed	80	34	36.17
Campanula L.	Wild/weed	7	7	7.45
Capsella Medik.	Wild/weed	1	1	1.06
Carex L.	Wild/weed	463	54	57.45
Centaurea sp.	Wild/weed	31	12	12.77
Chenopodium album L. type	Wild/weed	69	8	8.51
Chenopodium chenopodioides L. type	Wild/weed	4499	3	3.19
Chenopodium L.	Wild/weed	164	17	18.09
Conringia orientalis L.	Wild/weed	34	10	10.64
Convolvulus arvensis L. type	Wild/weed	194	39	41.49
Cornucopiae cucullatum L. type	Wild/weed	85	21	22.34
Crypsis aculeata (L.) Aiton type	Wild/weed	380	11	11.70
Descurainia sophia (L.) Webb	Wild/weed	2782177	43	45.74
Eragrostis N.M. Wolf	Wild/weed	653	8	8.51
Eremopyrum (Ledeb.) Jaub. & Spach	Wild/weed	43	23	24.47
Erodium L'Hérit.	Wild/weed	2	2	2.13
Euphorbia L.	Wild/weed	2	1	1.06
Fumaria L.	Wild/weed	10	5	5.32
Galium aparine L. type	Wild/weed	92	32	34.04
Galium verum L. type	Wild/weed	43	3	3.19
Geranium L., small type	Wild/weed	1	1	1.06
Helianthemum Adans.	Wild/weed	642	23	24.47
Heliotropium L.	Wild/weed	51	8	8.51
Hordeum murinum L. type	Wild/weed	13	11	11.70
Hordeum spontaneum C. Koch type	Wild/weed	7	4	4.26
Juncus L.	Wild/weed	3909	27	28.72
cf. *Lallemantia peltata* L.	Wild/weed	5	3	3.19
Lavatera L. type	Wild/weed	14	12	12.77

Table 4.5 Groups of wild taxa, their abundance and ubiquity

Taxa	GROUP	Number of items	Ubiquity	
			count	%
Leguminosae, small wild	Wild/weed	6346	81	86.17
Linum L.	Wild/weed	13	1	1.06
Malva L.	Wild/weed	12	8	8.51
Papaver L.	Wild/weed	2	1	1.06
Polygonatum Miller	Wild/weed	9	1	1.06
Polygonum aviculare aggregate	Wild/weed	1060	76	80.85
Polygonum convolvulus L.	Wild/weed	4	4	4.26
Potamogeton L.	Wild/weed	1	1	1.06
cf. *Potentilla* L. type	Wild/weed	3	2	2.13
Ranunculus L.	Wild/weed	2	2	2.13
Rumex L.	Wild/weed	559	23	24.47
Salsola L.	Wild/weed	45	17	18.09
cf. *Secale* sp.	Wild/weed	1	1	1.06
Sideritis L. type	Wild/weed	291	26	27.66
Silene sp.	Wild/weed	214	20	21.28
Sporobolus R. Br.	Wild/weed	5151	62	65.96
Stipa L.	Wild/weed	20	1	1.06
Suaeda L.	Wild/weed	8	1	1.06
Taeniatherum caput-medusae L.	Wild/weed	617	68	72.34
Teucrium L.	Wild/weed	21	4	4.26
Thymelea passerina (L.) Cosson & Germ. type	Wild/weed	27	9	9.57
Vaccaria pyramidata Medik.	Wild/weed	89	29	30.85
Valerianella Miller	Wild/weed	3	2	2.13
Verbena officinalis L.	Wild/weed	8	2	2.13
Vicia L./*Lathyrus* L.	Wild/weed	31	18	19.15
Viola L.	Wild/weed	1	1	1.06
Ziziphora capitata L./*persica* Bunge	Wild/weed	50	5	5.32
Buglossoides arvensis L. type	Wild/weed (non-charred)	102	27	28.72
Lithospermum officinale L.	Wild/weed (non-charred)	1	1	1.06
Eleocharis R. Br.	Wild/weed (non-charred)	53	6	6.38
Lemna L.	Wild/weed (non-charred)	112	5	5.32
Boraginaceae, large	Wild/weed - indeterminate	4	3	3.19
Caryophyllaceae	Wild/weed - indeterminate	25	4	4.26
Chenopodiaceae	Wild/weed - indeterminate	478	36	38.30
Chenopodiaceae/Caryophyllaceae	Wild/weed - indeterminate	75	13	13.83
Compositae/Dipsacaceae	Wild/weed - indeterminate	15	9	9.57
Compositae, large	Wild/weed - indeterminate	1	1	1.06
Compositae, small	Wild/weed - indeterminate	1	1	1.06
Crucifereae, large	Wild/weed - indeterminate	20	7	7.45
Crucifereae, medium	Wild/weed - indeterminate	248	22	23.40
Crucifereae, round type	Wild/weed - indeterminate	38	3	3.19
Cyperaceae	Wild/weed - indeterminate	599	40	42.55
Cyperaceae, small	Wild/weed - indeterminate	144	1	1.06
cf. *Dipsacaceae*	Wild/weed - indeterminate	1	1	1.06
Graminae, large	Wild/weed - indeterminate	323	66	70.21
Graminae, medium	Wild/weed - indeterminate	40	7	7.45
Graminae, small	Wild/weed - indeterminate	207	16	17.02
Lolium L./*Hordeum* L.	Wild/weed - indeterminate	2	1	1.06
cf. *Leguminosae*	Wild/weed - indeterminate	19	3	3.19
Leguminosae, small round type	Wild/weed - indeterminate	6	2	2.13
Malvaceae	Wild/weed - indeterminate	83	33	35.11
Polygonaceae	Wild/weed - indeterminate	515	33	35.11
cf. *Solanaceae*	Wild/weed - indeterminate	4	1	1.06

Table 4.5 - *continued* Groups of wild taxa, their abundance and ubiquity

	Sample number	Hulled wheat grain (after proportional re-assignment)	Hulled wheat glume bases	Grain:glume bases	Classification of samples based on grain:chaff ratio	Classification of samples based on hulled wheat content	*Descurainia* samples (≥70% of *Descurainia*)
1	11	117	21	5.57	*spikelet(/grain)*	**mixed crop**	X
2	171.329	180	56	3.21	*spikelet(/grain)*	**mixed crop**	
3	3742	90	41	2.20	*spikelet(/grain)*	**pulse sample**	
4	74.103	144	78	1.85	spikelet	hulled wheat	X
5	677	565	476	1.19	spikelet	hulled wheat	
6	23	76	86	0.88	spikelet	**mixed crop**	X
7	78	101	138	0.73	spikelet	hulled wheat	X
8	102	99	153	0.65	spikelet	hulled wheat	X
9	104	110	178	0.62	spikelet	hulled wheat	X
10	465	231	400	0.58	spikelet	hulled wheat	
11	135	53	94	0.56	spikelet	hulled wheat	
12	150	96	181	0.53	spikelet	hulled wheat	X
13	3351	40	85	0.47	spikelet	**mixed crop**	
14	4732	120	326	0.37	glume bases	**mixed crop**	
15	45	43	119	0.36	glume bases	**mixed crop**	X
16	101	14	40	0.35	glume bases	hulled wheat	X
17	31-27.33.37	199	606	0.33	glume bases	hulled wheat	
18	332	19	69	0.28	glume bases	hulled wheat	X
19	173	321	1236	0.26	glume bases	hulled wheat	
20	5030	65	251	0.26	glume bases	hulled wheat	
21	87	7	28	0.25	glume bases	**mixed crop**	X
22	282	56	231	0.24	glume bases	hulled wheat	X
23	2326	26	112	0.23	glume bases	hulled wheat	
24	395	136	586	0.23	glume bases	hulled wheat	
25	295	274	1192	0.23	glume bases	hulled wheat	
26	2763	31	143	0.22	glume bases	hulled wheat	
27	3297	141	656	0.21	glume bases	hulled wheat	
28	3666	157	735	0.21	glume bases	hulled wheat	
29	813	83	394	0.21	glume bases	hulled wheat	
30	2474	19	98	0.19	glume bases	hulled wheat	
31	3546	20	109	0.18	glume bases	hulled wheat	
32	1156	34	203	0.17	glume bases	hulled wheat	
33	1217	22	136	0.16	glume bases	hulled wheat	
34	520	119	743	0.16	glume bases	hulled wheat	
35	3247	67	428	0.16	glume bases	hulled wheat	
36	515	23	149	0.15	glume bases	hulled wheat	X
37	1631	42	273	0.15	glume bases	hulled wheat	
38	674	64	418	0.15	glume bases	hulled wheat	
39	5176	31	203	0.15	glume bases	hulled wheat	
40	1297.164	167	1100	0.15	glume bases	hulled wheat	
41	3324	16	108	0.15	glume bases	hulled wheat	
42	513	52	363	0.14	glume bases	hulled wheat	
43	3338	34	245	0.14	glume bases	hulled wheat	
44	1010	43	328	0.13	glume bases	hulled wheat	
45	2439	31	240	0.13	glume bases	hulled wheat	
46	516	33	267	0.12	glume bases	**mixed crop**	X
47	16-31.49.64.1732	242	1972	0.12	glume bases	hulled wheat	
48	2535	29	247	0.12	glume bases	hulled wheat	
49	31-48.49.51	202	1776	0.11	glume bases	hulled wheat	

Table 5.1 Classification of samples based on the hulled wheat grain:chaff ratio

	Sample number	Hulled wheat grain (after proportional re-assignment)	Hulled wheat glume bases	Grain:glume bases	Classification of samples based on grain:chaff ratio	Classification of samples based on hulled wheat content	*Descurainia* samples (≥70% of *Descurainia*)
50	2576	17	150	0.11	glume bases	hulled wheat	
51	3499	39	363	0.11	glume bases	hulled wheat	
52	128	47	453	0.10	glume bases	hulled wheat	
53	5019	3	29	0.10	glume bases	hulled wheat	
54	2792	17	167	0.10	glume bases	hulled wheat	
55	1038	62	616	0.10	glume bases	hulled wheat	
56	639	62	626	0.10	glume bases	hulled wheat	
57	144	4	41	0.10	glume bases	**pulse sample**	
58	198	38	390	0.10	glume bases	hulled wheat	
59	192	53	565	0.09	glume bases	hulled wheat	
60	2985	21	226	0.09	glume bases	hulled wheat	
61	26-25.36	27	291	0.09	glume bases	hulled wheat	
62	940	48	522	0.09	glume bases	hulled wheat	
63	366	42	461	0.09	glume bases	hulled wheat	
64	31-04.06.07	86	968	0.09	glume bases	hulled wheat	
65	345	13	148	0.09	glume bases	hulled wheat	
66	281	70	811	0.09	glume bases	hulled wheat	
67	2679	11	132	0.08	glume bases	hulled wheat	
68	1950	47	579	0.08	glume bases	hulled wheat	
69	4714	202	2496	0.08	glume bases	hulled wheat	
70	3099	38	473	0.08	glume bases	hulled wheat	
71	2425	23	294	0.08	glume bases	hulled wheat	
72	1804	107	1392	0.08	glume bases	hulled wheat	
73	232	33	451	0.07	glume bases	hulled wheat	
74	1735	43	594	0.07	glume bases	hulled wheat	
75	2236	15	209	0.07	glume bases	hulled wheat	
76	1795	50	703	0.07	glume bases	hulled wheat	
77	830	20	282	0.07	glume bases	hulled wheat	
78	27-13.15	48	686	0.07	glume bases	hulled wheat	
79	588	41	595	0.07	glume bases	hulled wheat	
80	3026	26	393	0.07	glume bases	hulled wheat	
81	1579	29	443	0.07	glume bases	hulled wheat	
82	3399	62	955	0.06	glume bases	hulled wheat	
83	26-37.38	18	282	0.06	glume bases	hulled wheat	
84	25-94.95.96	38	611	0.06	glume bases	hulled wheat	
85	4741	46	879	0.05	glume bases	hulled wheat	
86	535	27	587	0.05	glume bases	hulled wheat	X
87	539.551	51	1128	0.05	glume bases	hulled wheat	
88	4545.4626	97	2198	0.04	glume bases	hulled wheat	
89	1791	21	511	0.04	glume bases	hulled wheat	
90	1853	12	299	0.04	glume bases	hulled wheat	
91	904	41	1050	0.04	glume bases	hulled wheat	
92	4361	38	1024	0.04	glume bases	hulled wheat	
93	1669	24	729	0.03	glume bases	hulled wheat	
94	2661	1	95	0.01	glume bases	hulled wheat	

Table 5.1 - *continued* Classification of samples based on the hulled wheat grain:chaff ratio

	Taxa	Number of items	Ubiquity	
			count	%
1	*Adonis annua/aestivalis* L.	32	13	13.83
2	*Aeluropus* Trin.	11619	39	41.49
3	*Alisma* L.	17	6	6.38
4	*Anagallis* L.	7	2	2.13
5	*Androsace* L.	39	5	5.32
6	*Artemisia annua* L. type	1724	14	14.89
7	*Atriplex* L.	168	20	21.28
8	*Beta* L.	10	6	6.38
9	*Bolboschoenus glaucus* (Lam.) S.G. Smith	10779	93	98.94
10	*Boreava orientalis* Jaub. & Spach	20	8	8.51
11	*Bromus danthoniae* Trin. type	80	34	36.17
12	*Campanula* L.	7	7	7.45
13	*Capsella* Medik.	1	1	1.06
14	*Carex* L.	463	54	57.45
15	*Centaurea* sp.	31	12	12.77
16	*Chenopodium album* L. type	69	8	8.51
17	*Chenopodium chenopodioides* L. type	4499	3	3.19
18	*Chenopodium* L.	164	17	18.09
19	*Conringia orientalis* L.	34	10	10.64
20	*Convolvulus arvensis* L. type	194	39	41.49
21	*Cornucopiae cucullatum* L. type	85	21	22.34
22	*Crypsis aculeata* (L.) Aiton type	380	11	11.70
23	*Descurainia sophia* (L.) Webb	2782177	43	45.74
24	*Eragrostis* N.M. Wolf	653	8	8.51
25	*Eremopyrum* (Ledeb.) Jaub. & Spach	43	23	24.47
26	*Erodium* L'Hérit.	2	2	2.13
27	*Euphorbia* L.	2	1	1.06
28	*Fumaria* L.	10	5	5.32
29	*Galium aparine* L. type	92	32	34.04
30	*Galium verum* L. type	43	3	3.19
31	*Geranium* L., small type	1	1	1.06
32	*Helianthemum* Adans.	642	23	24.47
33	*Heliotropium* L.	51	8	8.51
34	*Hordeum murinum* L. type	13	11	11.70
35	*Hordeum spontaneum* C. Koch type	7	4	4.26
36	*Juncus* L.	3909	27	28.72
37	cf. *Lallemantia peltata* L.	5	3	3.19
38	*Lavatera* L. type	14	12	12.77
39	*Leguminosae* , small wild	6346	81	86.17
40	*Linum* L.	13	1	1.06
41	*Malva* L.	12	8	8.51
42	*Papaver* L.	2	1	1.06
43	*Polygonatum* Miller	9	1	1.06
44	*Polygonum aviculare* aggregate	1060	76	80.85
45	*Polygonum convolvulus* L.	4	4	4.26
46	*Potamogeton* L.	1	1	1.06
47	cf. *Potentilla* L. type	3	2	2.13
48	*Ranunculus* L.	2	2	2.13
49	*Rumex* L.	559	23	24.47
50	*Salsola* L.	45	17	18.09
51	cf. *Secale* sp.	1	1	1.06
52	*Sideritis* L. type	291	26	27.66
53	*Silene* sp.	214	20	21.28
54	*Sporobolus* R. Br.	5151	62	65.96
55	*Stipa* L.	20	1	1.06
56	*Suaeda* L.	8	1	1.06
57	*Taeniatherum caput-medusae* L.	617	68	72.34
58	*Teucrium* L.	21	4	4.26
59	*Thymelea passerina* (L.) Cosson & Germ. type	27	9	9.57
60	*Vaccaria pyramidata* Medik.	89	29	30.85
61	*Valerianella* Miller	3	2	2.13
62	*Verbena officinalis* L.	8	2	2.13
63	*Vicia* L./*Lathyrus* L.	31	18	19.15
64	*Viola* L.	1	1	1.06
65	*Ziziphora capitata* L./*persica* Bunge	50	5	5.32

Table 5.2 Wild/weed taxa included in the crop processing analysis

	Sample number	Predicted group (by-product)	Probability	SFH		SFL		BFH	BHH	SHH	SHL
				count	% *	count	% *	count	count	count	count
1	465	Winnowing	0.796	408	*73.91*	128	*23.19*	16	0	0	0
2	1631	Winnowing	0.804	40	*68.97*	16	*27.59*	1	0	0	1
3	904	Winnowing	0.827	42	*56.00*	32	*42.67*	1	0	0	0
4	135	Winnowing	0.832	43	*43.88*	25	*25.51*	29	0	1	0
5	1669	Winnowing	0.897	44	*55.70*	32	*40.51*	3	0	0	0
6	2326	Winnowing	0.910	47	*55.95*	24	*28.57*	5	0	8	0
7	2425	Winnowing	0.911	59	*69.41*	24	*28.24*	2	0	0	0
8	1804	Winnowing	0.942	17	*58.62*	8	*27.59*	3	1	0	0
9	2236	Winnowing	0.951	26	*68.42*	12	*31.58*	0	0	0	0
10	3099	Winnowing	0.963	56	*66.67*	24	*28.57*	4	0	0	0
11	395	Winnowing	0.970	674	*58.15*	450	*38.83*	19	0	16	0
12	813	Winnowing	0.980	33	*60.00*	20	*36.36*	2	0	0	0
13	830	Winnowing	0.984	37	*66.07*	16	*28.57*	2	1	0	0
14	2576	Winnowing	0.985	25	*60.98*	16	*39.02*	0	0	0	0
15	539.551	Winnowing	0.992	76	*53.15*	65	*45.45*	2	0	0	0
16	3297	Winnowing	0.994	777	*59.00*	411	*31.21*	46	3	80	0
17	3324	Winnowing	0.996	13633	*54.62*	11305	*45.29*	20	2	0	0
18	25-94.95.96	Winnowing	0.997	146	*71.92*	50	*24.63*	4	0	2	1
19	2985	Winnowing	0.998	53	*62.35*	24	*28.24*	3	0	4	1
20	3338	Winnowing	0.999	31	*52.54*	26	*44.07*	1	0	1	0
21	16-31.49.64.1732	Winnowing	0.999	278	*37.32*	413	*55.44*	26	1	27	0
22	1579	Winnowing	1.000	74	*39.57*	112	*59.89*	1	0	0	0
23	3351	Winnowing	1.000	633	*51.05*	600	*48.39*	6	0	0	1
24	4361	Winnowing	1.000	106	*23.40*	344	*75.94*	3	0	0	0
25	1950	Winnowing	1.000	24	*23.53*	64	*62.75*	4	1	9	0
26	3666	Winnowing	1.000	296	*20.33*	1160	*79.67*	0	0	0	0
27	3399	Winnowing	1.000	75	*34.88*	137	*63.72*	3	0	0	0
28	3742	Winnowing	1.000	464	*6.35*	6829	*93.43*	5	10	1	0
29	11	Fine-sieve	0.997	8138	*99.52*	8	*0.10*	23	0	8	0
30	23	Fine-sieve	0.997	5014	*99.92*	0	*0.00*	4	0	0	0
31	45	Fine-sieve	0.997	34529	*99.98*	0	*0.00*	7	1	0	0
32	74.103	Fine-sieve	0.993	1048	*96.15*	32	*2.94*	2	0	8	0
33	78	Fine-sieve	0.995	1518	*98.57*	16	*1.04*	6	0	0	0
34	87	Fine-sieve	0.997	14012	*99.99*	0	*0.00*	1	0	0	0
35	101	Fine-sieve	0.997	4182	*99.50*	16	*0.38*	5	0	0	0
36	102	Fine-sieve	0.998	8342	*99.88*	0	*0.00*	10	0	0	0
37	104	Fine-sieve	0.999	2442	*97.02*	64	*2.54*	11	0	0	0
38	128	Fine-sieve	0.996	88	*66.67*	22	*16.67*	18	0	4	0
39	144	Fine-sieve	0.996	115	*55.29*	0	*0.00*	76	0	17	0
40	150	Fine-sieve	0.997	4041	*99.58*	16	*0.39*	1	0	0	0
41	171.329	Fine-sieve	0.918	310	*90.91*	24	*7.04*	4	1	1	1
42	173	Fine-sieve	0.998	32	*80.00*	1	*2.50*	7	0	0	0
43	192	Fine-sieve	0.999	18	*81.82*	0	*0.00*	4	0	0	0
44	198	Fine-sieve	0.922	95	*78.51*	26	*21.49*	0	0	0	0
45	232	Fine-sieve	0.982	30	*76.92*	8	*20.51*	1	0	0	0
46	281	Fine-sieve	0.998	31	*67.39*	0	*0.00*	5	0	9	1
47	282	Fine-sieve	0.993	4053	*99.14*	32	*0.78*	2	0	1	0
48	295	Fine-sieve	0.968	100	*71.43*	34	*24.29*	5	1	0	0
49	332	Fine-sieve	0.997	85344	*99.97*	0	*0.00*	3	20	0	0

***** - percentage calculated from the total of classified wild/weed taxa in the sample

Table 5.6 Classification of samples by the discriminant analysis using crop processing physical weed types; proportions of two major types (small-free-heavy and small-free-light) and other types also shown

	Sample number	Predicted group (by-product)	Probability	SFH		SFL		BFH	BHH	SHH	SHL
				count	% *	count	% *	count	count	count	count
50	345	Fine-sieve	0.999	24	*92.31*	0	*0.00*	2	0	0	0
51	366	Fine-sieve	1.000	210	*98.13*	0	*0.00*	4	0	0	0
52	513	Fine-sieve	0.642	109	*75.17*	32	*22.07*	4	0	0	0
53	515	Fine-sieve	0.998	1184	*99.66*	4	*0.34*	0	0	0	0
54	516	Fine-sieve	0.996	2601045	*100.00*	0	*0.00*	18	0	0	0
55	520	Fine-sieve	0.934	598	*82.83*	120	*16.62*	3	1	0	0
56	535	Fine-sieve	0.994	6469	*99.43*	24	*0.37*	13	0	0	0
57	588	Fine-sieve	0.984	79	*73.83*	16	*14.95*	12	0	0	0
58	639	Fine-sieve	0.838	108	*73.97*	24	*16.44*	14	0	0	0
59	674	Fine-sieve	0.936	60	*72.29*	9	*10.84*	6	0	8	0
60	677	Fine-sieve	0.622	50	*73.53*	16	*23.53*	2	0	0	0
61	940	Fine-sieve	1.000	54	*90.00*	0	*0.00*	6	0	0	0
62	1010	Fine-sieve	0.694	83	*76.15*	24	*22.02*	2	0	0	0
63	1038	Fine-sieve	0.999	63	*77.78*	8	*9.88*	9	0	1	0
64	1156	Fine-sieve	0.995	40	*63.49*	12	*19.05*	11	0	0	0
65	1217	Fine-sieve	1.000	26	*100.00*	0	*0.00*	0	0	0	0
66	1297.164	Fine-sieve	0.997	241	*74.15*	24	*7.38*	59	0	1	0
67	1735	Fine-sieve	0.699	30	*45.45*	16	*24.24*	19	0	1	0
68	1791	Fine-sieve	0.990	36	*67.92*	4	*7.55*	13	0	0	0
69	1795	Fine-sieve	0.680	91	*63.64*	48	*33.57*	3	0	0	1
70	1853	Fine-sieve	0.826	53	*50.48*	46	*43.81*	6	0	0	0
71	2439	Fine-sieve	0.983	31	*77.50*	8	*20.00*	1	0	0	0
72	2474	Fine-sieve	1.000	29	*96.67*	0	*0.00*	1	0	0	0
73	2535	Fine-sieve	0.954	89	*81.65*	16	*14.68*	4	0	0	0
74	2661	Fine-sieve	0.612	28	*77.78*	8	*22.22*	0	0	0	0
75	2679	Fine-sieve	0.998	24	*96.00*	0	*0.00*	0	1	0	0
76	2763	Fine-sieve	1.000	34	*94.44*	0	*0.00*	2	0	0	0
77	2792	Fine-sieve	0.987	44	*74.58*	6	*10.17*	9	0	0	0
78	3026	Fine-sieve	0.999	63	*87.50*	0	*0.00*	9	0	0	0
79	3247	Fine-sieve	0.535	1180	*79.04*	272	*18.22*	31	2	8	0
80	3499	Fine-sieve	0.999	27	*100.00*	0	*0.00*	0	0	0	0
81	3546	Fine-sieve	0.544	71	*63.39*	32	*28.57*	9	0	0	0
82	4545.4626	Fine-sieve	0.996	159	*70.04*	49	*21.59*	17	1	0	1
83	4714	Fine-sieve	0.999	28	*77.78*	0	*0.00*	8	0	0	0
84	4732	Fine-sieve	0.787	94	*66.67*	24	*17.02*	22	0	0	1
85	4741	Fine-sieve	0.992	54	*68.35*	16	*20.25*	8	0	0	1
86	5019	Fine-sieve	0.998	463	*99.14*	1	*0.21*	3	0	0	0
87	5030	Fine-sieve	0.702	54	*51.92*	24	*23.08*	22	1	0	3
88	5176	Fine-sieve	1.000	51	*96.23*	2	*3.77*	0	0	0	0
89	26-25.36	Fine-sieve	0.898	68	*80.00*	16	*18.82*	1	0	0	0
90	26-37.38	Fine-sieve	0.925	75	*80.65*	16	*17.20*	2	0	0	0
91	27-13.15	Fine-sieve	0.960	247	*91.48*	16	*5.93*	5	0	2	0
92	31-04.06.07	Fine-sieve	0.947	433	*83.91*	60	*11.63*	20	2	1	0
93	31-27.33.37	Fine-sieve	0.752	1294	*70.56*	345	*18.81*	183	3	7	2
94	31-48.49.51	Fine-sieve	0.617	241	*60.71*	81	*20.40*	74	1	0	0
			UBIQUITY	94	***100.00***	75	***79.79***	84	19	25	12

***** - percentage calculated from the total of classified wild/weed taxa in the sample

Table 5.6 - *continued* Classification of samples by the discriminant analysis using crop processing physical weed types; proportions of two major types (small-free-heavy and small-free-light) and other types also shown

	Sample number	Predicted group (by-product)	Hulled wheat grain:chaff ratio group	Crop group	*Descurainia* sample
1	3351	Winnowing	spikelet	mixed crop	
2	3742	Winnowing	spikelet(/grain)	pulse	
3	465	*Winnowing*	*spikelet*	*hulled wheat*	
4	135	*Winnowing*	*spikelet*	*hulled wheat*	
5	25-94.95.96	Winnowing	glume bases	hulled wheat	
6	16-31.49.64.1732	Winnowing	glume bases	hulled wheat	
7	4361	Winnowing	glume bases	hulled wheat	
8	3666	Winnowing	glume bases	hulled wheat	
9	3399	Winnowing	glume bases	hulled wheat	
10	3338	Winnowing	glume bases	hulled wheat	
11	3324	Winnowing	glume bases	hulled wheat	
12	3297	Winnowing	glume bases	hulled wheat	
13	3099	Winnowing	glume bases	hulled wheat	
14	2985	Winnowing	glume bases	hulled wheat	
15	2576	Winnowing	glume bases	hulled wheat	
16	2425	Winnowing	glume bases	hulled wheat	
17	2326	Winnowing	glume bases	hulled wheat	
18	2236	Winnowing	glume bases	hulled wheat	
19	1950	Winnowing	glume bases	hulled wheat	
20	1804	Winnowing	glume bases	hulled wheat	
21	1669	Winnowing	glume bases	hulled wheat	
22	1631	Winnowing	glume bases	hulled wheat	
23	1579	Winnowing	glume bases	hulled wheat	
24	904	Winnowing	glume bases	hulled wheat	
25	830	Winnowing	glume bases	hulled wheat	
26	813	Winnowing	glume bases	hulled wheat	
27	539.551	Winnowing	glume bases	hulled wheat	
28	395	Winnowing	glume bases	hulled wheat	
29	23	Fine-sieve	spikelet	mixed crop	**X**
30	11	Fine-sieve	spikelet(/grain)	mixed crop	**X**
31	516	Fine-sieve	glume bases	mixed crop	**X**
32	87	Fine-sieve	glume bases	mixed crop	**X**
33	45	Fine-sieve	glume bases	mixed crop	**X**
34	171.329	Fine-sieve	spikelet(/grain)	**mixed crop**	
35	4732	Fine-sieve	glume bases	**mixed crop**	
36	144	*Fine-sieve*	glume bases	pulse	
37	**677**	*Fine-sieve*	*spikelet*	*hulled wheat*	
38	31-48.49.51	Fine-sieve	glume bases	hulled wheat	
39	31-27.33.37	Fine-sieve	glume bases	hulled wheat	
40	31-04.06.07	Fine-sieve	glume bases	hulled wheat	
41	27-13.15	Fine-sieve	glume bases	hulled wheat	
42	26-37.38	Fine-sieve	glume bases	hulled wheat	
43	26-25.36	Fine-sieve	glume bases	hulled wheat	
44	5176	Fine-sieve	glume bases	hulled wheat	
45	5030	Fine-sieve	glume bases	hulled wheat	
46	5019	Fine-sieve	glume bases	hulled wheat	
47	4741	Fine-sieve	glume bases	hulled wheat	
48	4714	Fine-sieve	glume bases	hulled wheat	

Table 5.7 Combined results of crop-based and weed-based crop processing analysis also showing classification of samples based on their crop (hulled wheat) and *Descurainia* content

	Sample number	Predicted group (by-product)	Hulled wheat grain:chaff ratio group	Crop group	*Descurainia* sample
49	4545.4626	Fine-sieve	glume bases	hulled wheat	
50	3546	Fine-sieve	glume bases	hulled wheat	
51	3499	Fine-sieve	glume bases	hulled wheat	
52	3247	Fine-sieve	glume bases	hulled wheat	
53	3026	Fine-sieve	glume bases	hulled wheat	
54	2792	Fine-sieve	glume bases	hulled wheat	
55	2763	Fine-sieve	glume bases	hulled wheat	
56	2679	Fine-sieve	glume bases	hulled wheat	
57	2661	Fine-sieve	glume bases	hulled wheat	
58	2535	Fine-sieve	glume bases	hulled wheat	
59	2474	Fine-sieve	glume bases	hulled wheat	
60	2439	Fine-sieve	glume bases	hulled wheat	
61	1853	Fine-sieve	glume bases	hulled wheat	
62	1795	Fine-sieve	glume bases	hulled wheat	
63	1791	Fine-sieve	glume bases	hulled wheat	
64	1735	Fine-sieve	glume bases	hulled wheat	
65	1297.164	Fine-sieve	glume bases	hulled wheat	
66	1217	Fine-sieve	glume bases	hulled wheat	
67	1156	Fine-sieve	glume bases	hulled wheat	
68	1038	Fine-sieve	glume bases	hulled wheat	
69	1010	Fine-sieve	glume bases	hulled wheat	
70	940	Fine-sieve	glume bases	hulled wheat	
71	674	Fine-sieve	glume bases	hulled wheat	
72	639	Fine-sieve	glume bases	hulled wheat	
73	588	Fine-sieve	glume bases	hulled wheat	
74	520	Fine-sieve	glume bases	hulled wheat	
75	513	Fine-sieve	glume bases	hulled wheat	
76	366	Fine-sieve	glume bases	hulled wheat	
77	345	Fine-sieve	glume bases	hulled wheat	
78	295	Fine-sieve	glume bases	hulled wheat	
79	281	Fine-sieve	glume bases	hulled wheat	
80	232	Fine-sieve	glume bases	hulled wheat	
81	198	Fine-sieve	glume bases	hulled wheat	
82	192	Fine-sieve	glume bases	hulled wheat	
83	173	Fine-sieve	glume bases	hulled wheat	
84	128	Fine-sieve	glume bases	hulled wheat	
85	150	Fine-sieve	spikelet	hulled wheat	X
86	104	Fine-sieve	spikelet	hulled wheat	X
87	102	Fine-sieve	spikelet	hulled wheat	X
88	78	Fine-sieve	spikelet	hulled wheat	X
89	74.103	Fine-sieve	spikelet	hulled wheat	X
90	535	Fine-sieve	glume bases	hulled wheat	X
91	515	Fine-sieve	glume bases	hulled wheat	X
92	332	Fine-sieve	glume bases	hulled wheat	X
93	282	Fine-sieve	glume bases	hulled wheat	X
94	101	Fine-sieve	glume bases	hulled wheat	X

Table 5.7 - *continued* Combined results of crop-based and weed-based crop processing analysis also showing classification of samples based on their crop *(hulled wheat) and Descurainia* content

	Sample number	Building/ Space	Context	Sheep/goat pellets (count)	Fragmentary dung (ml)	Dung fragments (ml) with embedded plant material		Plant material embedded in dung				
						cf. *Carex* and cf. *Sporobolus*	'oily' seeds	*Bolboschoenus* seed	*Sporobolus* seed	cf. *Chenopodium* seed	*Polygonum* cf. *aviculare* seed	cf. pistachio shell fragments
1	31-27.33.37	181	ash deposit in external midden	2	0.93		0.10					
2	3099	6	rake-out	2								
3	3297	181	external midden	2	0.03							
4	345	2	midden in abandoned building	1								
5	4361	3	fire installation	1	0.40	0.10		**1**	**16**			
6	4545.4626	85	external midden	1	0.51							1
7	27-13.15	18	bin fill	1								
8	31-48.49.51	181	external midden (burning event)	1					**8**			
9	520	1	oven floor	1								
10	1853	3	roof tumble	1	0.25							
11	2792	6	bin fill		0.40							
12	16-31.49.64.1732	3	roof collapse		0.40							
13	1038	115	external midden		0.25					**8**		
14	1669	3	roof		0.20							
15	1579	3	roof tumble		0.15							
16	1631	3	roof collapse		0.15							
17	3399	3	ash lens above floor		0.10	0.01		**1**	**1**			
18	135	1	basin fill		0.10							
19	1795	3	burnt deposit (floor occupation)		0.10							
20	3742	181	burnt deposit in external midden		0.10							
21	4714	3	basin fill		0.10							
22	677	115	external midden		0.05							
23	4741	85	external midden		0.05							
24	539.551	1	building fill		0.02							
25	465	1	oven floor								**1**	
26	513	2	midden in abandoned building								**2**	
27	830	2	midden in abandoned building					**1**				
28	904	109	oven					**1**				

Table 5.9 List of samples containing dung pellets, fragmented dung and/or plant material embedded in dung

	DRY					WET		
	arable	ruderal				freshwater	saline	
TAXA	fields, cultivated land	waste places, roadsides ditches	rocky slopes, screes, hillsides	steppe, grassland	clay soil, sandy places	river or lake banks, marshes	salty places, salt marshes	'open' (usually stagnant) water
Cornucopiae cucullatum L. type	+					(+)		
Vaccaria pyramidata Medik.	+							
Boreava orientalis Jaub. & Spach	+	+						
Capsella Medik.	+	+						
Chenopodium album L. type	+	+						
***Chenopodium* L.**	+	+						
Conringia orientalis L.	+	+						
Fumaria L.	+	+						
Leguminosae , small wild	+	+						
Bromus danthoniae Trin. type	+	+	+					
cf. *Lallemantia peltata* L.	+	+	+					
Hordeum spontaneum C. Koch type	+	+	+					
Polygonum convolvulus L.	+	+	+					
Convolvulus arvensis L. type	+	+	+	+		+		
Adonis annua/aestivalis L.	+	+	+	+				
Buglossoides arvensis L.	+	+	+	+				
cf. *Secale* sp.	+	+	+	+				
Galium aparine L. type	+	+	+	+				
Galium verum L. type	+	+	+	+				
Heliotropium L.	+	+	+	+				
Hordeum murinum L. type	+	+	+	+				
Papaver L.	+	+	+	+				
Sideritis L. type	+	+	+	+				
Silene sp.	+	+	+	+				
Beta L.	+	+		+				
Malva L.	+	+		+				
Valerianella Miller	+		+					
Centaurea sp.	+	+	+	+	+			
Thymelea passerina (L.) Cosson & Germ. type	+		+	+	+			
Artemisia annua L. type	+	+		+	+			
Descurainia sophia (L.) Webb		+						
Llithospermum officinale L.		+						
***Polygonum aviculare* aggregate**		+	+					
Lavatera L. type		+	+					
Verbena officinalis L.		+	+		+			

Table 5.10 Habitat preferences of the wild/weed taxa

	DRY					WET		
	arable	ruderal				freshwater	saline	
TAXA	fields, cultivated land	waste places, roadsides ditches	rocky slopes, screes, hillsides	steppe, grassland	clay soil, sandy places	river or lake banks, marshes	salty places, salt marshes	'open' (usually stagnant) water
Linum L.		+	+	+				
Teucrium L.		+	+	+				
Ziziphora capitata L./*persica* Bunge		+	+	+				
Eremopyrum (Ledeb.) Jaub. & Spach		+	+	+	+	(+)		
Erodium L'Hérit.		+	+	+	+			
Androsace L.			+					
Polygonatum Miller			+					
Viola L.			+					
Stipa L.			+	+				
Taeniatherum caput-medusae L.			+	+				
Helianthemum Adans.			+	+	+			
cf. *Potentilla* L. type		+	+			+		
Geranium L., small type	+	+	+			+		
Rumex L.	+	+	+			+		
Anagallis L.	+		+		+	+		
Ranunculus L.	+		+			+		+
Atriplex L.	+	+		+	+	+	+	
Euphorbia L.	+	+	+	+	+	+	+	
Eragrostis N.M. Wolf	+	+	+		+	+	+	
***Carex* L.**	+	+	+			+	+	
Suaeda L.	+	+			+		+	
***Bolboschoenus glaucus* (Lam.) S.G. Smith**						+		
Phragmites australis (Cav.) Trin.						+		
Eleocharis R. Br.			+			+	+	
Crypsis aculeata (L.) Aiton type					+	+	+	
Juncus L.						+	+	
Aeluropus Trin.						+	+	
Chenopodium chenopodioides L. type					+		+	
Salsola L.							+	
***Sporobolus* R. Br.**							+	
Alisma L.								+
Lemna L.								+
Potamogeton L.								+

Table 5.10 - *continued* Habitat preferences of the wild/weed taxa

TAXA	Classification (group)	FRUITING TIME												Fruiting estimate relative to harvest time
		DEC	JAN	FEB	MARCH	APRIL	MAY	**JUNE**	**JULY**	AUG	SEP	OCT	NOV	
Buglossoides arvensis L.	EARLY			o	x	x	x	**x**						before and at harvest time
Valerianella Miller	EARLY				o	x	x	**x**	**x**					before and at harvest time
Conringia orientalis L.	EARLY				o	x	x	**x**						before and at harvest time
Cornucopiae cucullatum L. type	EARLY				o	x	x							before and at harvest time
Vaccaria pyramidata Medik.	EARLY					o	x							before and at harvest time
Adonis annua/aestivalis L.	EARLY					o	x	**x**						before and at harvest time
Descurainia sophia (L.) Webb	EARLY					o	x	**x**						before and at harvest time
Boreava orientalis Jaub. & Spach	EARLY						o	**x**						at harvest time
Beta L.	EARLY						o	**x**	**x**					at harvest time
cf. *Lallemantia peltata* L.	EARLY						o	**x**	**x**					at harvest time
Llithospermum officinale L.	EARLY						o	**x**	**x**					at harvest time
Polygonatum Miller	EARLY						o	**x**	**x**					at harvest time
Euphorbia L.	INTERMEDIATE		o	x	x	x	x	**x**	**x**	x	x	x		before, at and after harvest time
Ranunculus L.	INTERMEDIATE		o	x	x	x	x	**x**	**x**	x	x	x		before, at and after harvest time
Erodium L'Hérit.	INTERMEDIATE		o	x	x	x	x	**x**	**x**	x	x			before, at and after harvest time
Vicia L./*Lathyrus* L.	INTERMEDIATE		o	x	x	x	x	**x**	**x**	x	x			before, at and after harvest time
Galium aparine L. type	INTERMEDIATE			o	x	x	x	**x**	**x**	x	x			before, at and after harvest time
Galium verum L. type	INTERMEDIATE			o	x	x	x	**x**	**x**	x	x			before, at and after harvest time
Silene sp.	INTERMEDIATE			o	x	x	x	**x**	**x**	x	x			before, at and after harvest time
Anagallis L.	INTERMEDIATE				o	x	x	**x**	**x**	x	x	x		before, at and after harvest time
Bromus danthoniae Trin. type	INTERMEDIATE				o	x	x	**x**	**x**	x	x	x		before, at and after harvest time
Eleocharis R. Br.	INTERMEDIATE				o	x	x	**x**	**x**	x	x			before, at and after harvest time
Geranium L., small type	INTERMEDIATE				o	x	x	**x**	**x**	x	x			before, at and after harvest time
Juncus L.	INTERMEDIATE				o	x	x	**x**	**x**	x	x			before, at and after harvest time
Linum L.	INTERMEDIATE				o	x	x	**x**	**x**	x	x			before, at and after harvest time
Papaver L.	INTERMEDIATE				o	x	x	**x**	**x**	x	x			before, at and after harvest time
Teucrium L.	INTERMEDIATE				o	x	x	**x**	**x**	x	x			before, at and after harvest time
Bolboschoenus glaucus (Lam.) S.G. Smith	INTERMEDIATE				o	x	x	**x**	**x**	x				before, at and after harvest time
Eremopyrum (Ledeb.) Jaub. & Spach	INTERMEDIATE				o	x	x	**x**	**x**	x				before, at and after harvest time
Fumaria L.	INTERMEDIATE				o	x	x	**x**	**x**	x				before, at and after harvest time
Helianthemum Adans.	INTERMEDIATE				o	x	x	**x**	**x**	x				before, at and after harvest time
Viola L.	INTERMEDIATE				o	x	x	**x**	**x**	x				before, at and after harvest time
Centaurea sp.	INTERMEDIATE					o	x	**x**	**x**	x	x	x		before, at and after harvest time
Crypsis aculeata (L.) Aiton type	INTERMEDIATE					o	x	**x**	**x**	x	x	x		before, at and after harvest time
Malva L.	INTERMEDIATE					o	x	**x**	**x**	x	x	x		before, at and after harvest time

Table 5.11 Classification of the wild/weed taxa based on their fruiting time in relation to the harvest time

TAXA	Classification (group)	FRUITING TIME												Fruiting estimate relative to harvest time
		DEC	JAN	FEB	MARCH	APRIL	MAY	**JUNE**	**JULY**	AUG	SEP	OCT	NOV	
Sporobolus R. Br.	INTERMEDIATE					o	x	**x**	**x**	x	x	x		before, at and after harvest time
Alisma L.	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Androsace L.	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
cf. *Potentilla* L. type	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Convolvulus arvensis L. type	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Hordeum spontaneum C. Koch type	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Lavatera L. type	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Leguminosae , small wild	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Potamogeton L.	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Sideritis L. type	INTERMEDIATE					o	x	**x**	**x**	x	x			before, at and after harvest time
Hordeum murinum L. type	INTERMEDIATE					o	x	**x**	**x**	x				before, at and after harvest time
Ziziphora capitata L./*persica* Bunge	INTERMEDIATE					o	x	**x**	**x**	x				before, at and after harvest time
Lemna L.	INTERMEDIATE					o	x	**x**	**x**	x				before, at and after harvest time
Taeniatherum caput-medusae L.	LATE						o	**x**	**x**	x				at and after harvest time
Eragrostis N.M. Wolf	LATE						o	**x**	**x**	x	x	x	x	at and after harvest time
Heliotropium L.	LATE						o	**x**	**x**	x	x	x		at and after harvest time
Aeluropus Trin.	LATE						o	**x**	**x**	x	x	x		at and after harvest time
Rumex L.	LATE						o	**x**	**x**	x	x			at and after harvest time
Salsola L.	LATE						o	**x**	**x**	x	x			at and after harvest time
Suaeda L.	LATE						o	**x**	**x**	x	x			at and after harvest time
Atriplex L.	LATE						o	**x**	**x**	x				at and after harvest time
Chenopodium album L. type	LATE						o	**x**	**x**	x				at and after harvest time
Chenopodium chenopodioides L. type	LATE						o	**x**	**x**	x				at and after harvest time
Chenopodium L.	LATE						o	**x**	**x**	x				at and after harvest time
cf. *Secale* sp.	LATE						o	**x**	**x**	x				at and after harvest time
Stipa L.	LATE						o	**x**	**x**	x				at and after harvest time
Polygonum convolvulus L.	LATE						o	**x**	**x**	x	x			at and after harvest time
Artemisia annua L. type	LATE							**o**	**x**	x	x	x		at and after harvest time
Polygonum aviculare aggregate	LATE							**o**	**x**	x	x	x	x	at and after harvest time
Verbena officinalis L.	LATE							**o**	**x**	x				at and after harvest time
Phragmites australis (Cav.) Trin.	LATE									o	x	x		after harvest time
Thymelea passerina (L.) Cosson & Germ. type	year-round	x		o	x	x	x	**x**	**x**	x	x	x	x	fruiting year round
Capsella Medik.	year-round	o	x	x	x	x	x	**x**	**x**	x	x	x	x	fruiting year round
Carex L.	non-grouped													

Table 5.11 - *continued* Classification of the wild/weed taxa based on their fruiting time in relation to the harvest time

	Sample number	Predicted group	Probability
1	144	*Fine-sieve by-product*	0.959
2	281	*Fine-sieve by-product*	0.970
3	11	Çatalhöyük	0.972
4	23	Çatalhöyük	0.988
5	45	Çatalhöyük	0.980
6	74.103	Çatalhöyük	0.974
7	78	Çatalhöyük	0.981
8	87	Çatalhöyük	0.968
9	101	Çatalhöyük	0.994
10	102	Çatalhöyük	0.991
11	104	Çatalhöyük	0.999
12	128	Çatalhöyük	0.937
13	135	Çatalhöyük	0.984
14	150	Çatalhöyük	0.993
15	171.329	Çatalhöyük	0.814
16	173	Çatalhöyük	0.762
17	192	Çatalhöyük	1.000
18	198	Çatalhöyük	0.999
19	232	Çatalhöyük	0.993
20	282	Çatalhöyük	0.988
21	295	Çatalhöyük	1.000
22	332	Çatalhöyük	0.974
23	345	Çatalhöyük	0.879
24	366	Çatalhöyük	0.955
25	395	Çatalhöyük	1.000
26	465	Çatalhöyük	1.000
27	513	Çatalhöyük	1.000
28	515	Çatalhöyük	0.988
29	516	Çatalhöyük	0.974
30	520	Çatalhöyük	1.000
31	535	Çatalhöyük	0.986
32	539.551	Çatalhöyük	1.000
33	588	Çatalhöyük	0.999
34	639	Çatalhöyük	0.999
35	674	Çatalhöyük	0.877
36	677	Çatalhöyük	1.000
37	813	Çatalhöyük	1.000
38	830	Çatalhöyük	1.000
39	904	Çatalhöyük	1.000
40	940	Çatalhöyük	0.814
41	1010	Çatalhöyük	1.000
42	1038	Çatalhöyük	0.976
43	1156	Çatalhöyük	0.996
44	1217	Çatalhöyük	0.979
45	1297.16	Çatalhöyük	0.964
46	1735	Çatalhöyük	0.929
47	1791	Çatalhöyük	0.977

	Sample number	Predicted group	Probability
48	1804	Çatalhöyük	0.999
49	1950	Çatalhöyük	1.000
50	2236	Çatalhöyük	1.000
51	2326	Çatalhöyük	0.988
52	2425	Çatalhöyük	1.000
53	2439	Çatalhöyük	0.999
54	2474	Çatalhöyük	0.952
55	2535	Çatalhöyük	0.999
56	2576	Çatalhöyük	1.000
57	25-94.95.96	Çatalhöyük	1.000
58	26-25.36	Çatalhöyük	0.999
59	26-37.38	Çatalhöyük	1.000
60	2661	Çatalhöyük	1.000
61	2679	Çatalhöyük	0.976
62	27-13.15	Çatalhöyük	0.995
63	2763	Çatalhöyük	0.940
64	2792	Çatalhöyük	0.997
65	2985	Çatalhöyük	1.000
66	3026	Çatalhöyük	0.893
67	3099	Çatalhöyük	1.000
68	31-04.06.07	Çatalhöyük	0.997
69	31-27.33.37	Çatalhöyük	0.997
70	31-48.49.51	Çatalhöyük	1.000
71	3247	Çatalhöyük	0.999
72	3297	Çatalhöyük	1.000
73	3324	Çatalhöyük	1.000
74	3338	Çatalhöyük	1.000
75	3351	Çatalhöyük	1.000
76	3499	Çatalhöyük	0.977
77	3546	Çatalhöyük	0.998
78	3666	Çatalhöyük	1.000
79	3742	Çatalhöyük	1.000
80	1579	Çatalhöyük	1.000
81	1631	Çatalhöyük	1.000
82	16-31.49.64.1732	Çatalhöyük	1.000
83	1669	Çatalhöyük	1.000
84	1795	Çatalhöyük	1.000
85	1853	Çatalhöyük	1.000
86	3399	Çatalhöyük	1.000
87	4361	Çatalhöyük	1.000
88	4545.4626	Çatalhöyük	0.994
89	4714	Çatalhöyük	0.626
90	4732	Çatalhöyük	0.996
91	4741	Çatalhöyük	0.997
92	5019	Çatalhöyük	0.973
93	5030	Çatalhöyük	0.994
94	5176	Çatalhöyük	0.997

Table 5.12 Classification of the samples entered as a 'fifth' (Çatalhöyük) group in the discriminant analysis, in addition to the four ethnographic (Amorgos) groups of samples

TAXA	Observed in relation to dung	HABITAT		Classification based on fruiting time	Crop processing physical type	'Expected' crop processing stage (based on physical type)
		dry	wet			
Sporobolus R. Br.	**x**		**x**	intermediate	**SFL**	*winnowing by-product*
Carex L.	**x**	x	x		SFH	fine-sieve by-product
Bolboschoenus glaucus (Lam.) S.G. Smith	**x**		**x**	intermediate	SFH	fine-sieve by-product
Chenopodium L.	**x**	x		late	SFH	fine-sieve by-product
Polygonum aviculare aggregate	**x**	x		late	SFH	fine-sieve by-product
Aeluropus Trin.			**x**	late	**SFL**	*winnowing by-product*
Phragmites australis (Cav.) Trin.			**x**	late	**SFL**	*winnowing by-product*
Crypsis aculeata (L.) Aiton type			**x**	intermediate	**SFL**	*winnowing by-product*
Juncus L.			**x**	intermediate	**SFL**	*winnowing by-product*
Alisma L.			**x**	intermediate	**SFL**	
Lemna L.			**x**	intermediate	**SFL**	
Chenopodium chenopodioides L. type			**x**	late	SFH	fine-sieve by-product
Salsola L.			**x**	late	SFH	fine-sieve by-product
Eleocharis R. Br.			**x**	intermediate	SFH	fine-sieve by-product
Potamogeton L.			**x**	intermediate	SFH	
Artemisia annua L. type		x		**late**	**SFL**	*winnowing by-product*
Eragrostis N.M. Wolf		x	x	**late**	**SFL**	*winnowing by-product*
Polygonum convolvulus L.		x		late	BFH	product
Taeniatherum caput-medusae L.		x		late	BFH	product
Chenopodium album L. type		x		late	SFH	fine-sieve by-product
Heliotropium L.		x		late	SFH	fine-sieve by-product
Verbena officinalis L.		x		late	SFH	fine-sieve by-product
Atriplex L.		x	x	late	SFH	fine-sieve by-product
Rumex L.		x	x	late	SFH	fine-sieve by-product
Suaeda L.		x	x	late	SFH	fine-sieve by-product
cf. *Secale* sp.		x		late	BHH	coarse-sieve by-product
Stipa L.		x		late	BHH	coarse-sieve by-product
Adonis annua/aestivalis L.		x		early	BFH	product
Boreava orientalis Jaub. & Spach		x		early	BFH	product
cf. *Lallemantia peltata* L.		x		early	BFH	product
Cornucopiae cucullatum L. type		x		early	SFH	fine-sieve by-product
Conringia orientalis L.		x		early	SFH	fine-sieve by-product
Descurainia sophia (L.) Webb		x		early	SFH	fine-sieve by-product
Vaccaria pyramidata Medik.		x		early	SFH	fine-sieve by-product
Valerianella Miller		x		early	SFH	fine-sieve by-product

Table 5.14 Summary of habitat, seasonality and crop processing physical characteristics of the wild/weed taxa

TAXA	Observed in relation to dung	HABITAT		Classification based on fruiting time	Crop processing physical type	'Expected' crop processing stage (based on physical type)
		dry	wet			
Beta L.		x		early	BHH	coarse-sieve by-product
Polygonatum Miller		x		early	BHH	coarse-sieve by-product
Buglossoides arvensis L. type		x		early		
Lithospermum officinale L.		x		early		
Helianthemum Adans.		x		intermediate	**SFL**	*winnowing by-product*
Convolvulus arvensis L. type		x		intermediate	BFH	product
Centaurea sp.		x		intermediate	BFH	product
Fumaria L.		x		intermediate	BFH	product
Galium aparine L. type		x		intermediate	BFH	product
Hordeum spontaneum C. Koch type		x		intermediate	BFH	product
Vicia L./*Lathyrus* L.		x		intermediate	BFH	product
Androsace L.		x		intermediate	SFH	fine-sieve by-product
Bromus danthoniae Trin. type		x		intermediate	SFH	fine-sieve by-product
Eremopyrum (Ledeb.) Jaub. & Spach		x		intermediate	SFH	fine-sieve by-product
Erodium L'Hérit.		x		intermediate	SFH	fine-sieve by-product
Galium verum L. type		x		intermediate	SFH	fine-sieve by-product
Leguminosae , small wild		x		intermediate	SFH	fine-sieve by-product
Linum L.		x		intermediate	SFH	fine-sieve by-product
Sideritis L. type		x		intermediate	SFH	fine-sieve by-product
Teucrium L.		x		intermediate	SFH	fine-sieve by-product
Viola L.		x		intermediate	SFH	fine-sieve by-product
Ziziphora capitata L./*persica* Bunge		x		intermediate	SFH	fine-sieve by-product
Anagallis L.		x	x	intermediate	SFH	fine-sieve by-product
cf. *Potentilla* L. type		x	x	intermediate	SFH	fine-sieve by-product
Euphorbia L.		x	x	intermediate	SFH	fine-sieve by-product
Geranium L., small type		x	x	intermediate	SFH	fine-sieve by-product
Ranunculus L.		x	x	intermediate	SFH	fine-sieve by-product
Lavatera L. type		x		intermediate	BHH	coarse-sieve by-product
Malva L.		x		intermediate	SHH	coarse-sieve by-product
Silene sp.		x		intermediate	SHH	coarse-sieve by-product
Hordeum murinum L. type		x		intermediate	SHL	coarse-sieve by-product
Papaver L.		x		intermediate	SHL	coarse-sieve by-product
Capsella Medik.		x		year-round	SFH	fine-sieve by-product
Thymelea passerina (L.) Cosson & Germ. type		x		year-round	SFH	fine-sieve by-product

Table 5.14 - *continued* Summary of habitat, seasonality and crop processing physical characteristics of the wild/weed taxa

Figure 6.1
Correspondence analysis plot of the 94 samples and 75 taxa showing relative proportions of crop and wild material

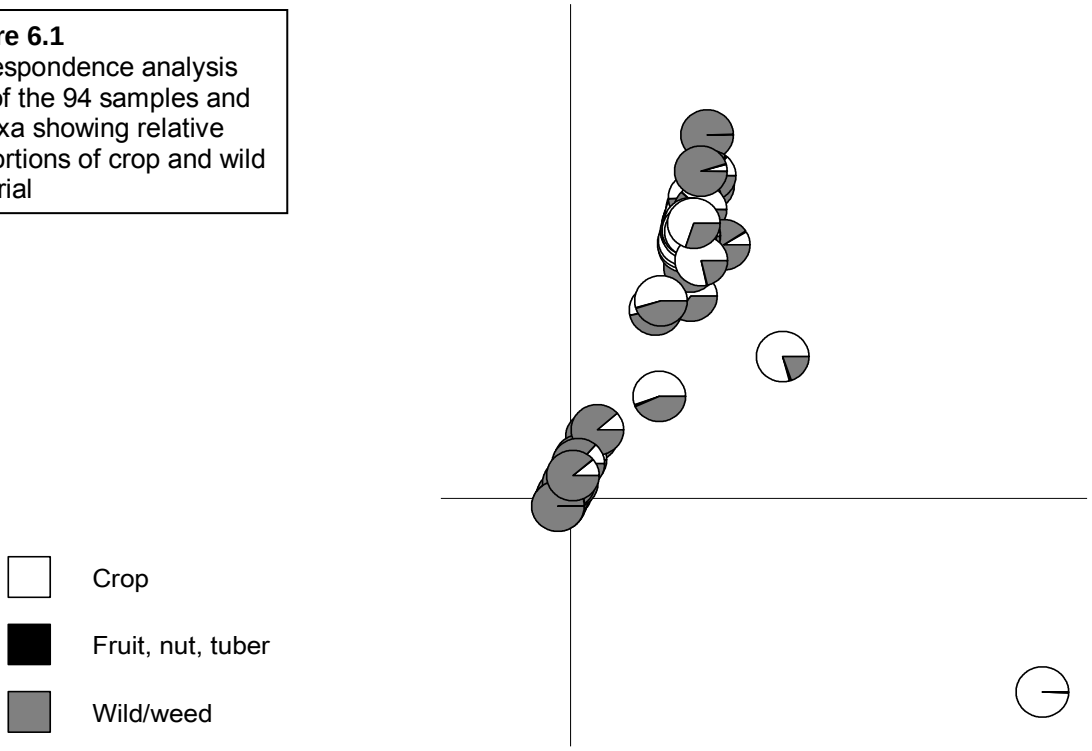
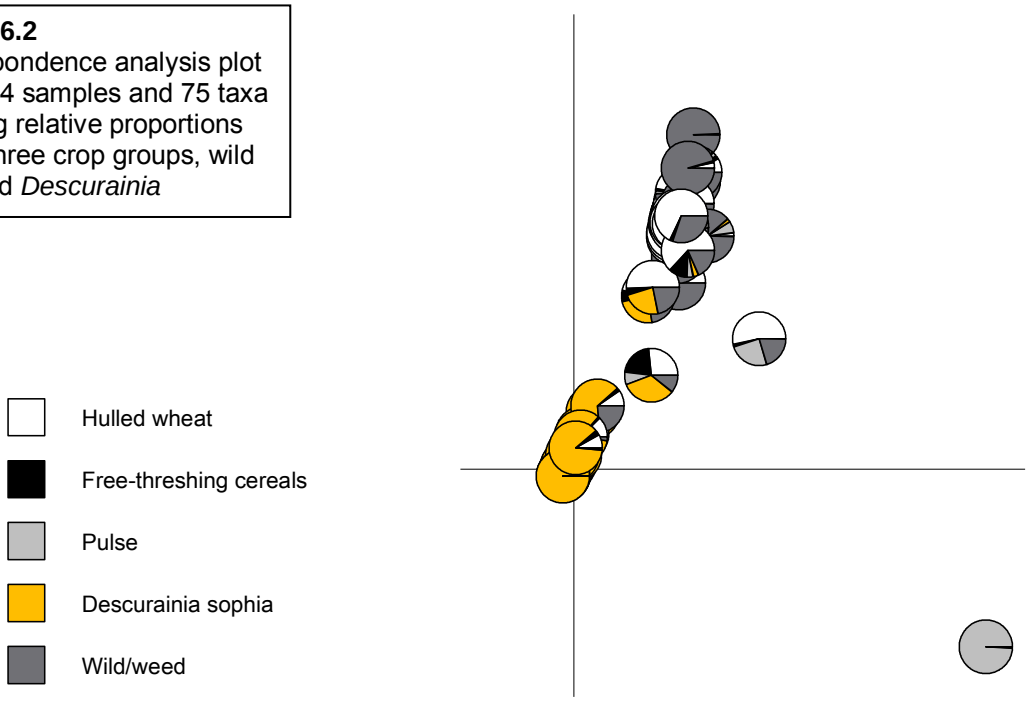


Figure 6.2
Correspondence analysis plot of the 94 samples and 75 taxa showing relative proportions of the three crop groups, wild taxa and *Descurainia*



Figures 6.1-6.2	Axes	**1**	**2**	**3**	**4**	Total inertia
	Eigenvalues	0.975	0.927	0.724	0.672	4.805
Cumulative percentage variance of species data		20.3	39.6	54.7	68.6	

Figure 6.3
Correspondence analysis plot of the 92 samples and 75 taxa showing relative proportions of the three crop groups, all wild taxa and *Descurainia*

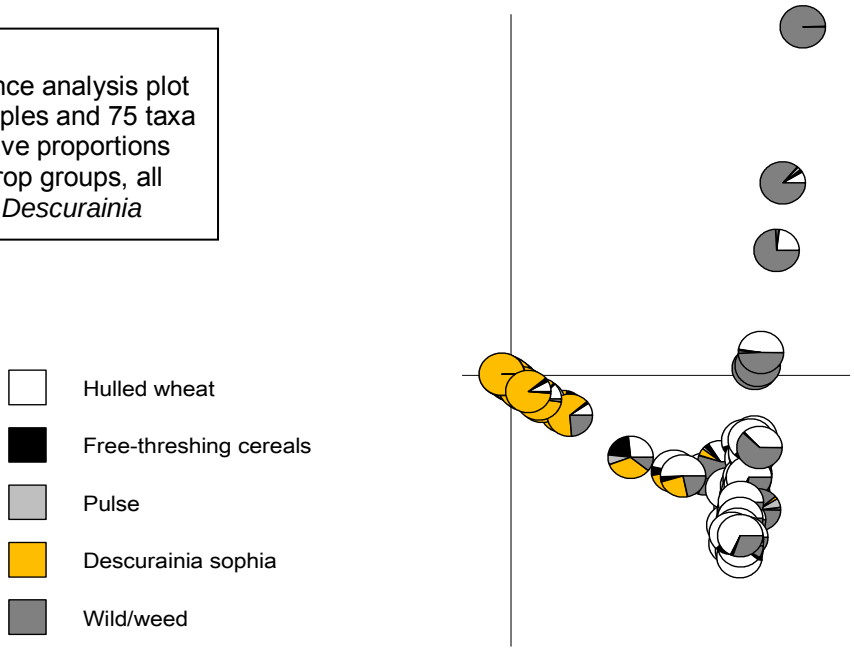
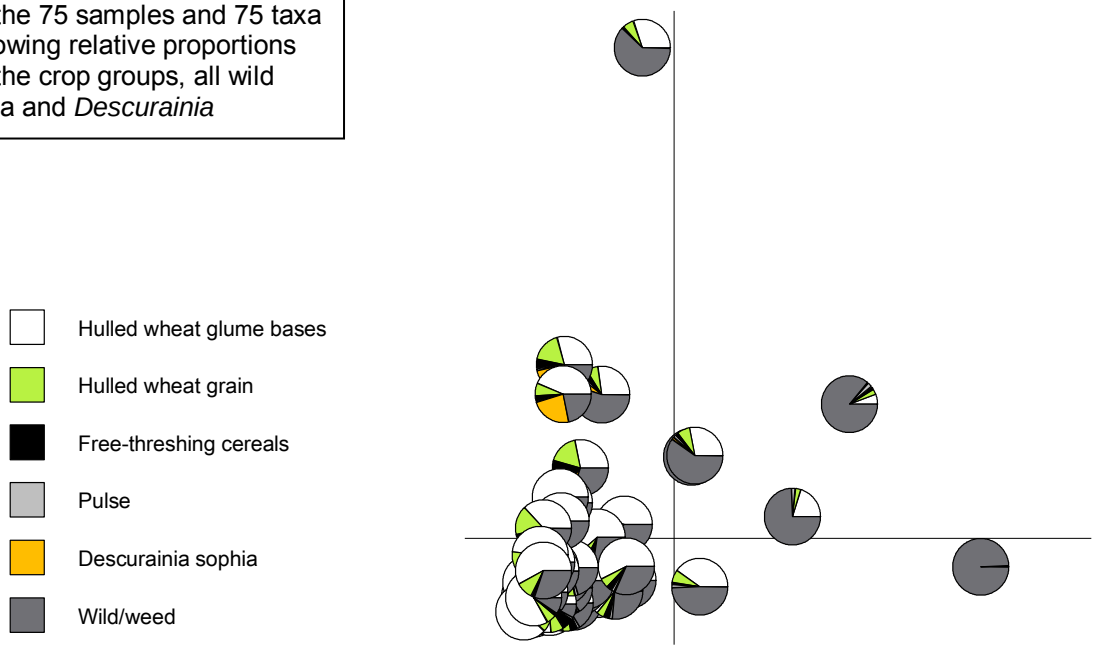


Figure 6.3 Axes	**1**	**2**	**3**	**4**	Total inertia
Eigenvalues	0.945	0.682	0.591	0.174	3.252
Cumulative percentage variance of species data	29	50	68.2	73.6	

Figure 6.4
Correspondence analysis plot of the 75 samples and 75 taxa showing relative proportions of the crop groups, all wild taxa and *Descurainia*



Figures 6.4-6.23 Axes	**1**	**2**	**3**	**4**	Total inertia
Eigenvalues	0.706	0.218	0.194	0.122	2.01
Cumulative percentage variance of species data	35.1	46	55.6	61.7	

Figure 6.5
Correspondence analysis species plot showing distribution of some major crop types and wild taxa

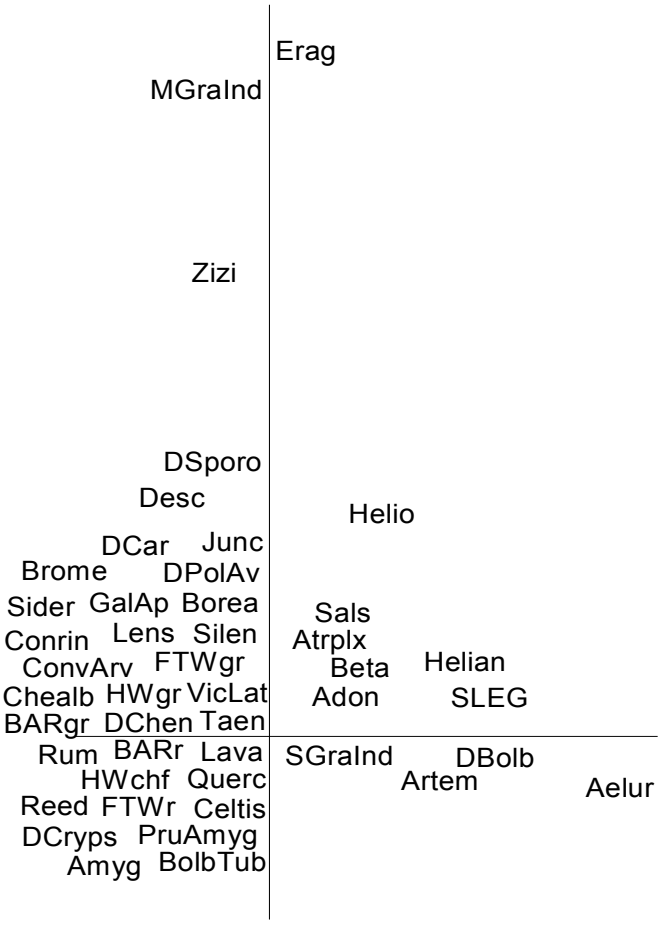


Figure 6.6
Correspondence analysis plot showing the 28 dung-containing samples

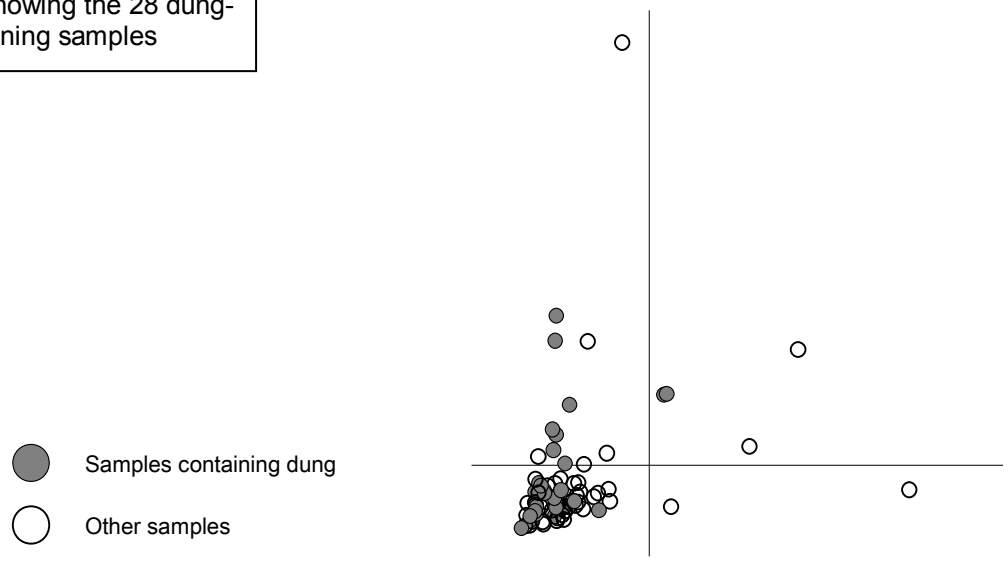
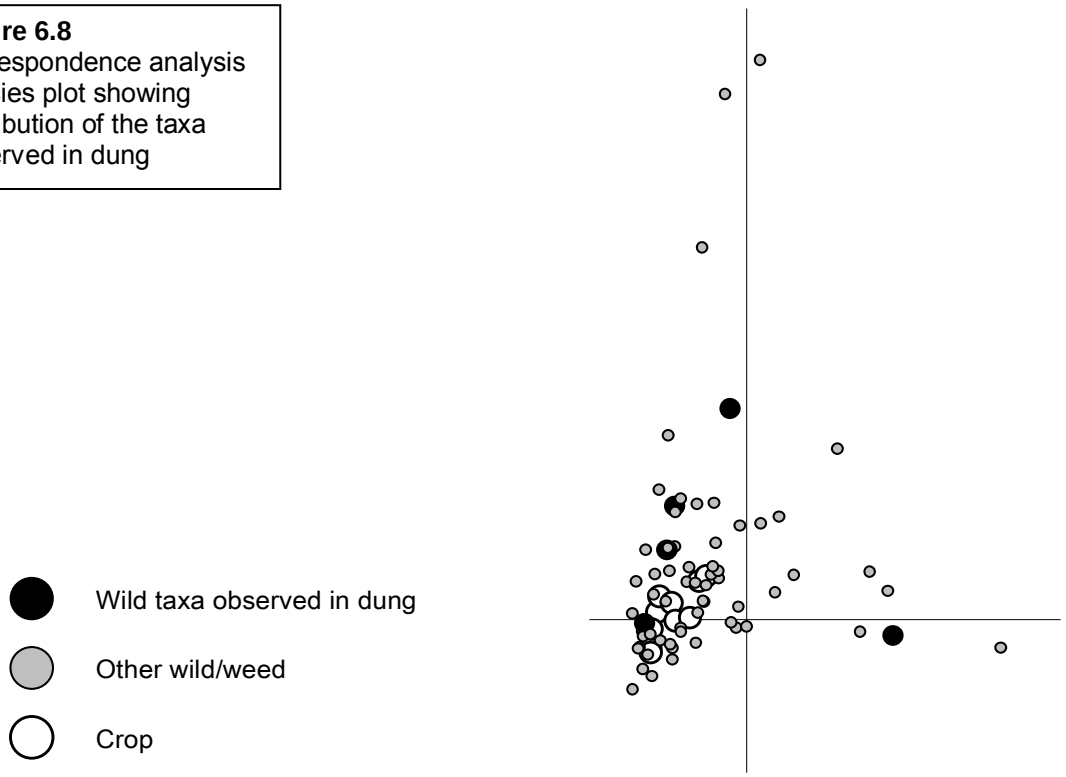
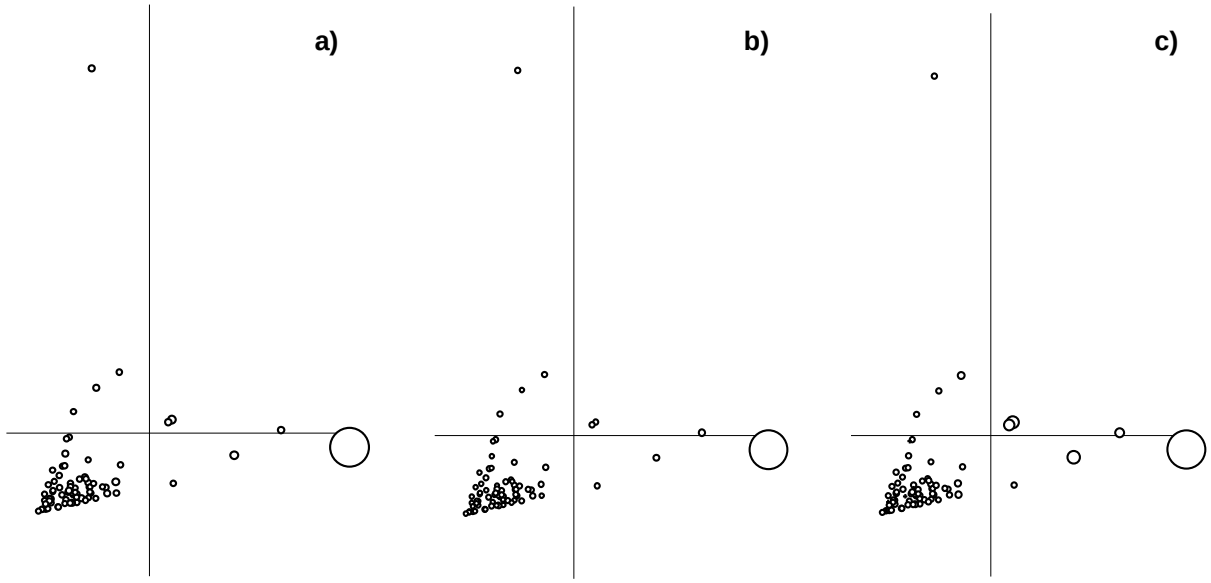


Figure 6.7
Correspondence analysis plot showing relative proportions of the taxa observed in dung



Figure 6.8
Correspondence analysis species plot showing distribution of the taxa observed in dung





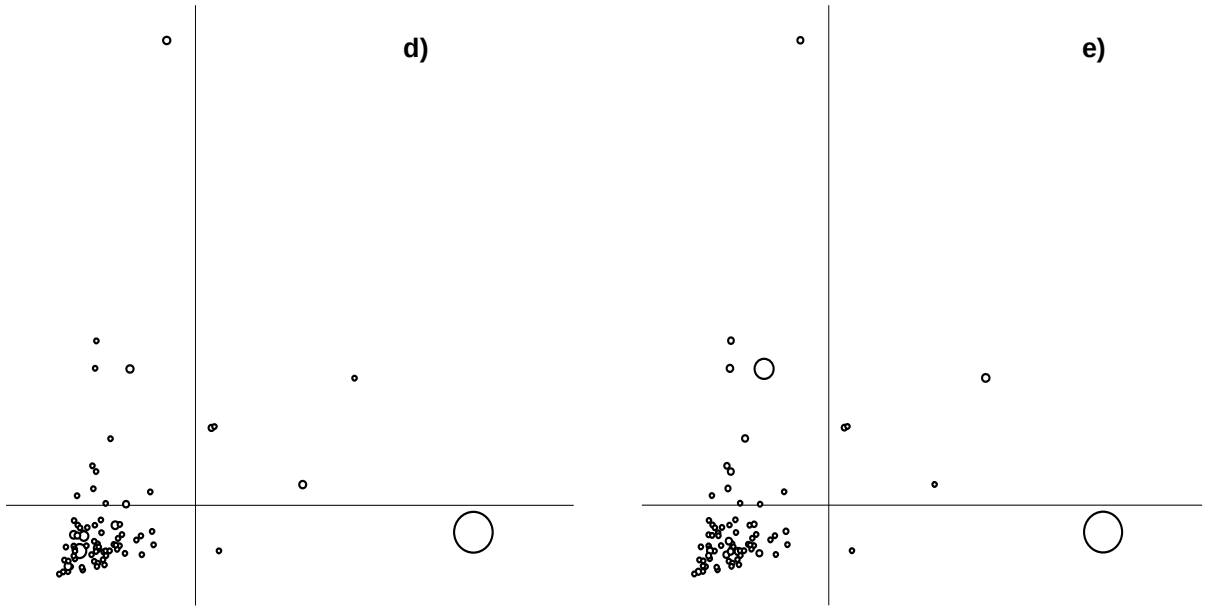


Figure 6.9a-e Correspondence analysis attribute plots showing the contribution of the selected wild/weed taxa (circles illustrate absolute number of seeds in a sample): **a)** *Bolboschoenus* **b)** *Aeluropus* **c)** small-seeded legumes **d)** *Artemisia* **e)** *Helianthemum*

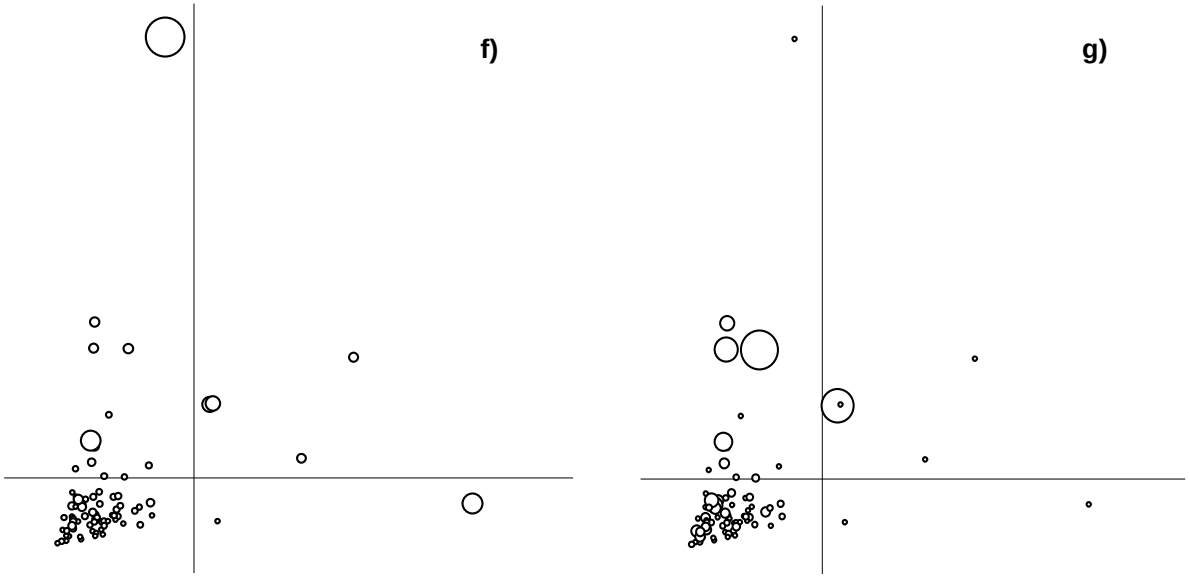
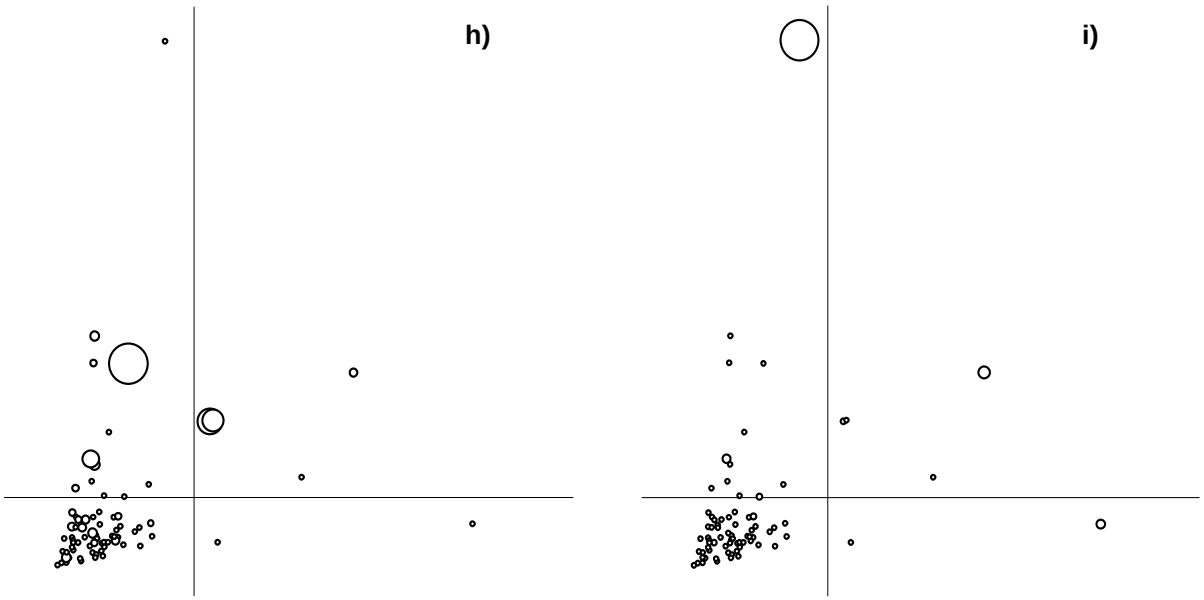


Figure 6.9f-i Correspondence analysis attribute plots showing the contribution of the selected wild/weed taxa (circles illustrate absolute number of seeds in a sample): **f)** *Sporobolus* **g)** *Carex* **h)** *Juncus* **i)** *Eragrostis*



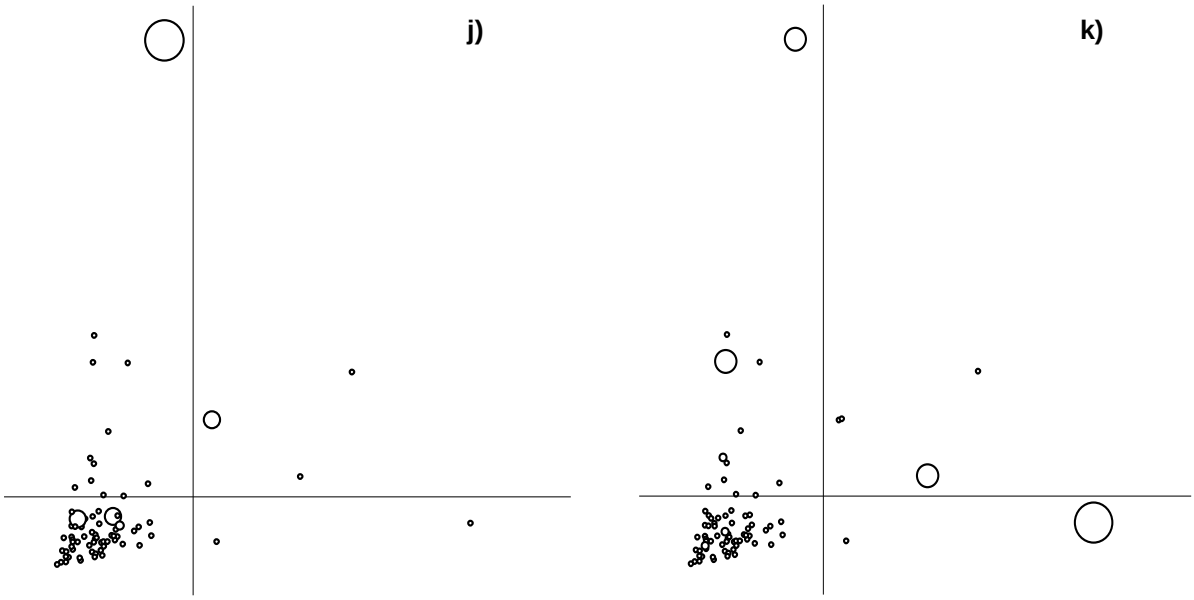


Figure 6.9j-k Correspondence analysis attribute plots showing the contribution of the selected wild/weed taxa (circles illustrate absolute number of seeds in a sample): **j)** *Ziziphora* **k)** *Heliotropium*

Figure 6.10
Correspondence analysis species plot showing distribution of the taxa observed in dung and the taxa co-occurring with these

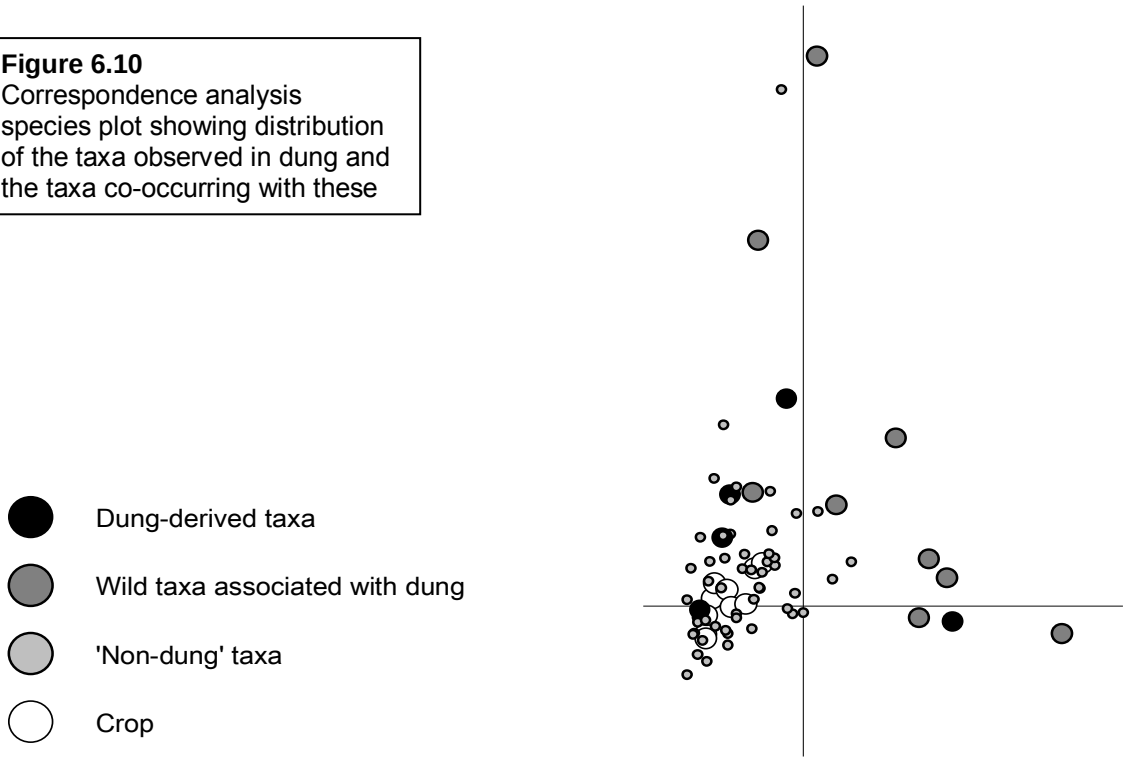


Figure 6.11
Correspondence analysis plot showing relative proportions of crop processing physical types of the wild/weed taxa

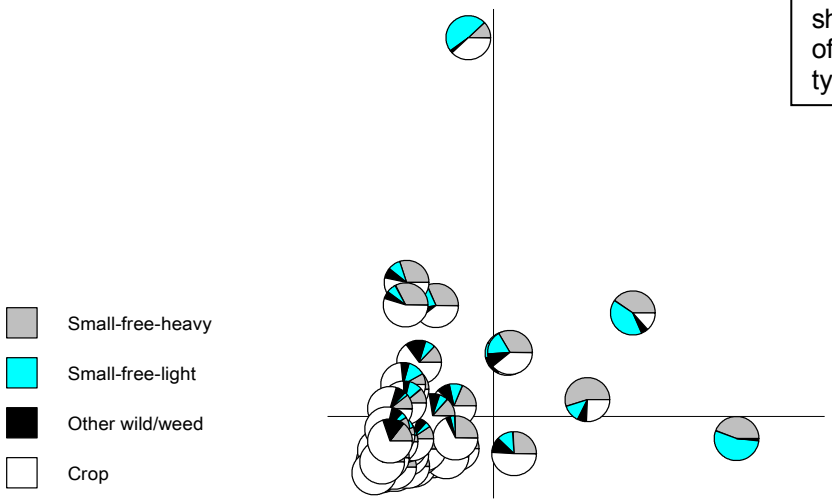


Figure 6.12
Correspondence species analysis plot showing distribution of crop processing physical types of the wild/weed taxa

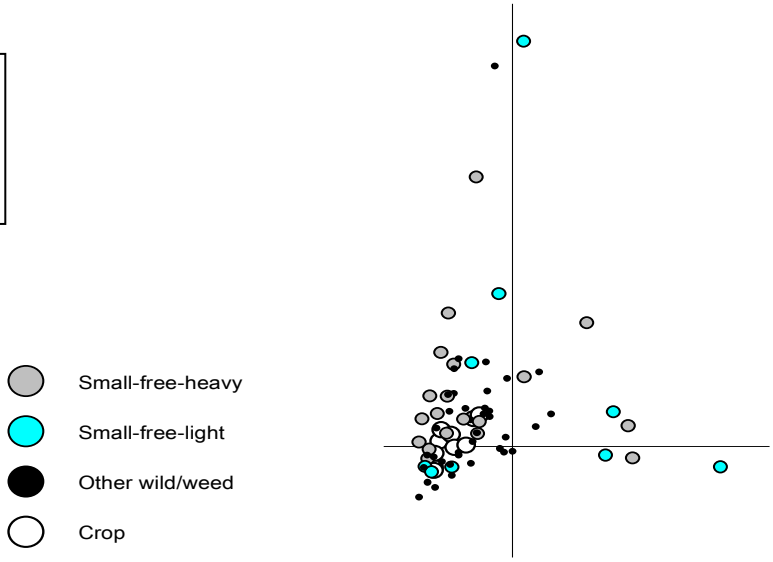


Figure 6.13
Correspondence analysis plot showing relative proportions of different seasonality (fruiting time) categories of the wild/weed taxa

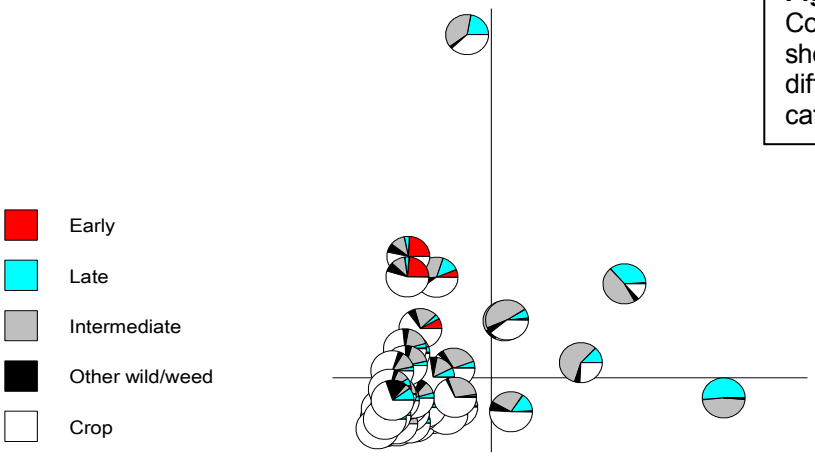


Figure 6.14
Correspondence analysis species plot showing distribution of different seasonality (fruiting time) categories of the wild/weed taxa

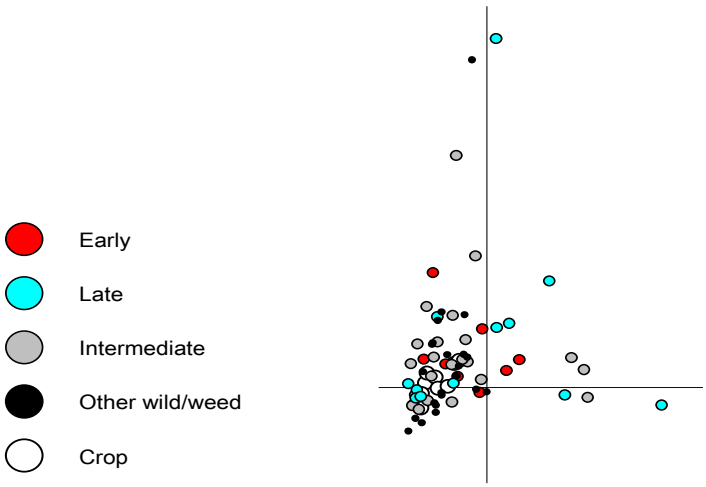


Figure 6.15
Correspondence analysis plot showing relative proportions of different habitat categories of the wild/weed taxa

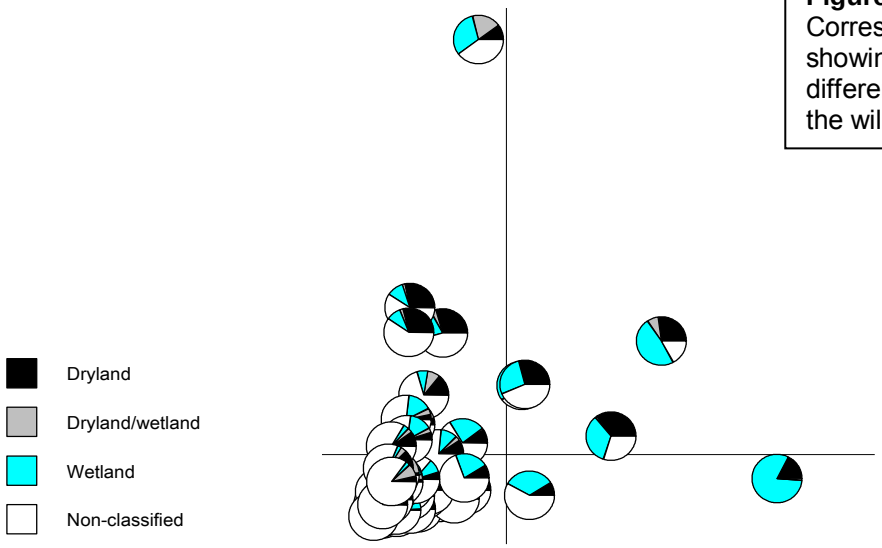


Figure 6.16
Correspondence species analysis plot showing distribution of different habitat categories of the wild/weed taxa

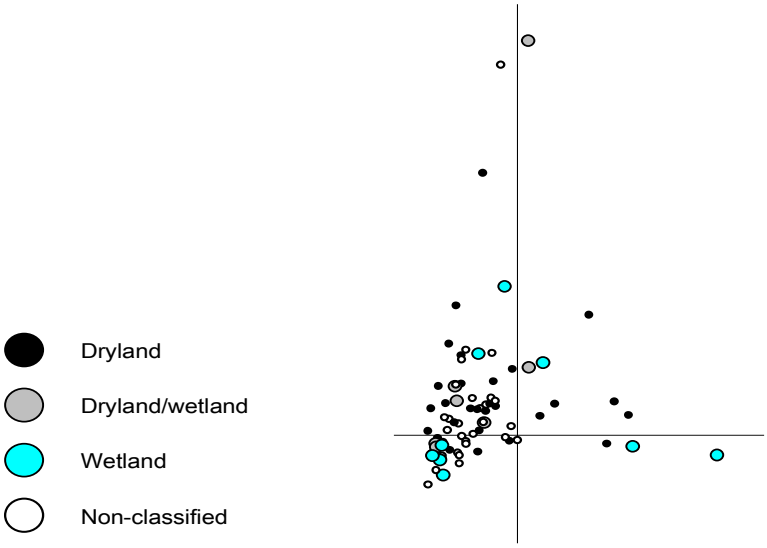


Figure 6.17
Correspondence analysis plot showing archaeological context types for the 75 samples

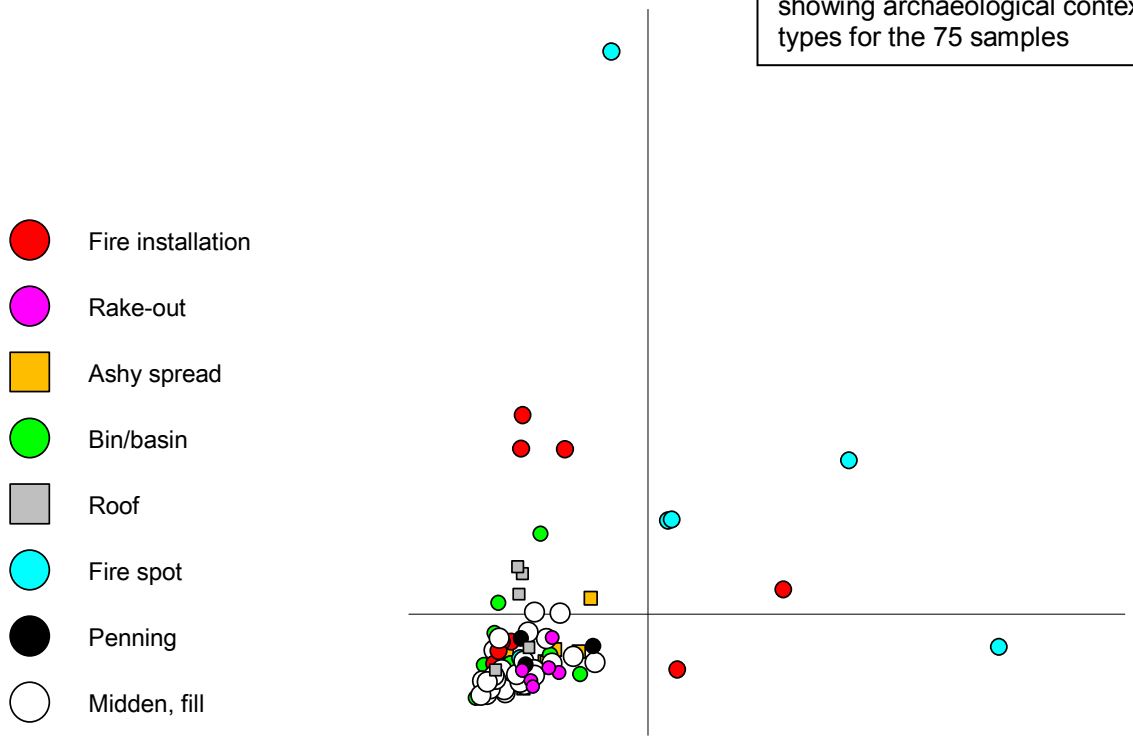
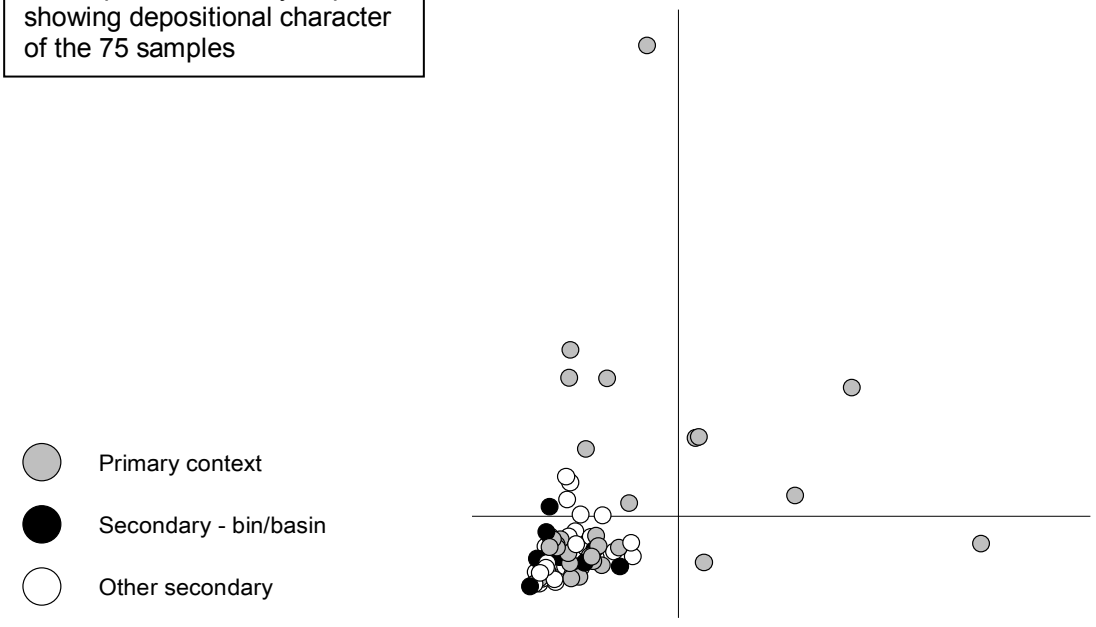


Figure 6.18
Correspondence analysis plot showing depositional character of the 75 samples



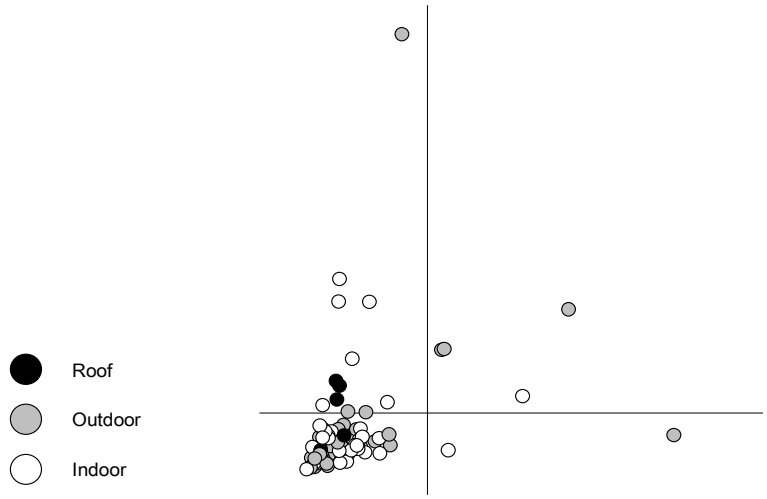


Figure 6.19
Correspondence analysis plot showing internal/external derivation ('location') of the 75 samples

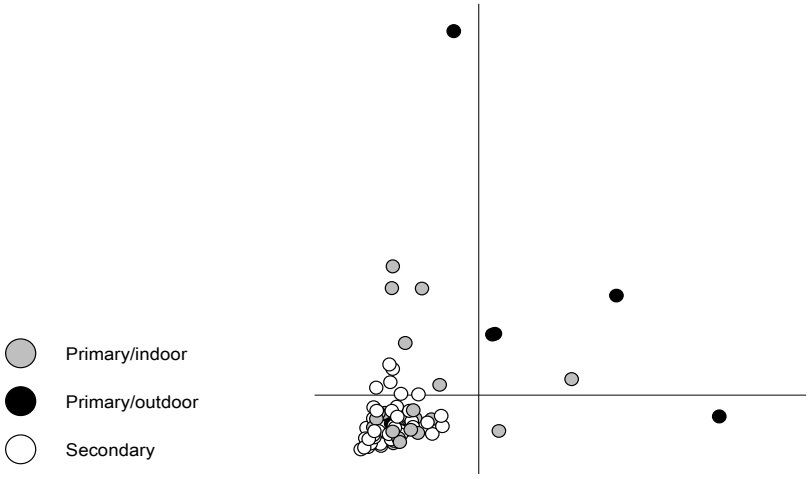


Figure 6.20
Correspondence analysis plot showing depositional character and location of the 75 samples

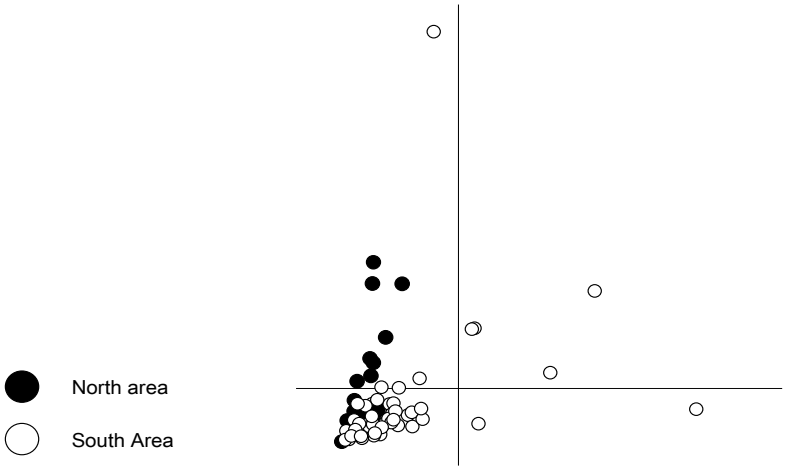


Figure 6.21
Correspondence analysis plot showing the excavation areas for the 75 samples

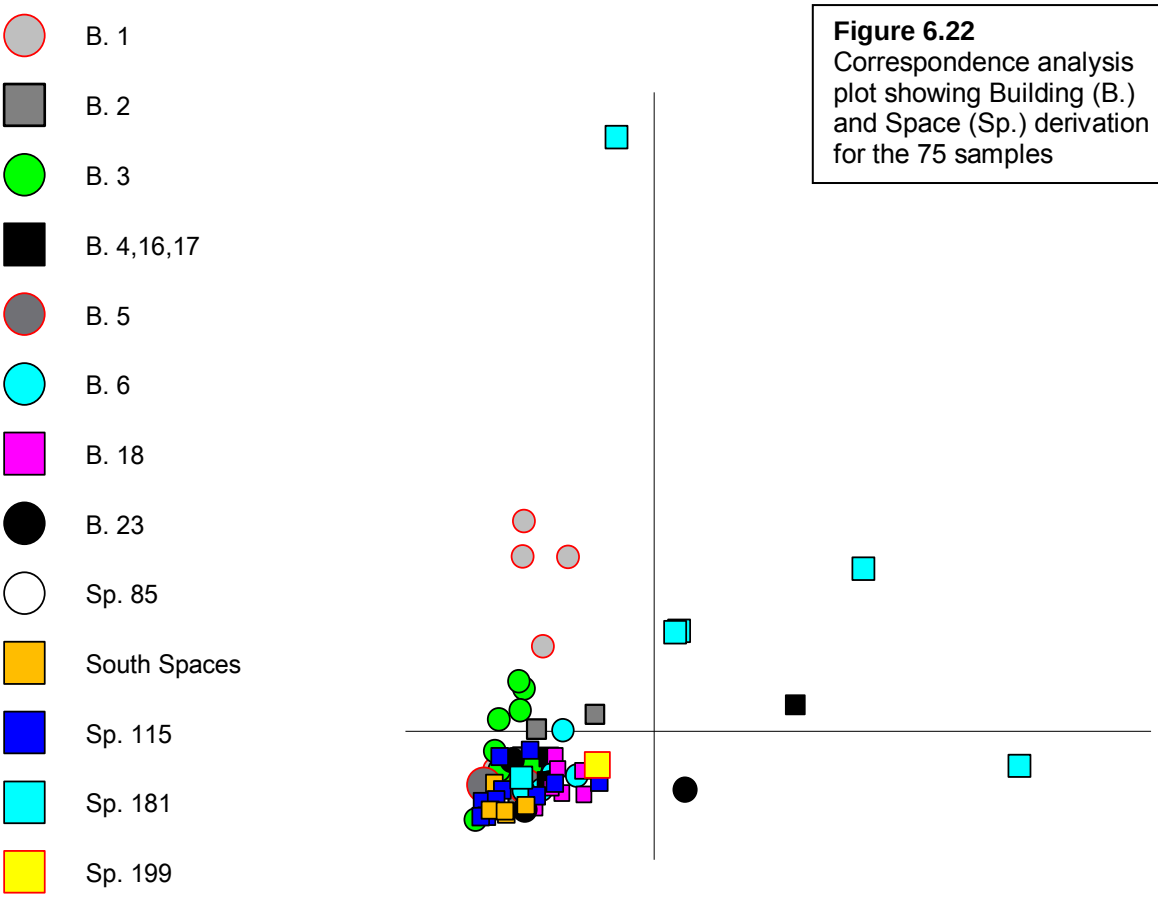


Figure 6.22
Correspondence analysis plot showing Building (B.) and Space (Sp.) derivation for the 75 samples

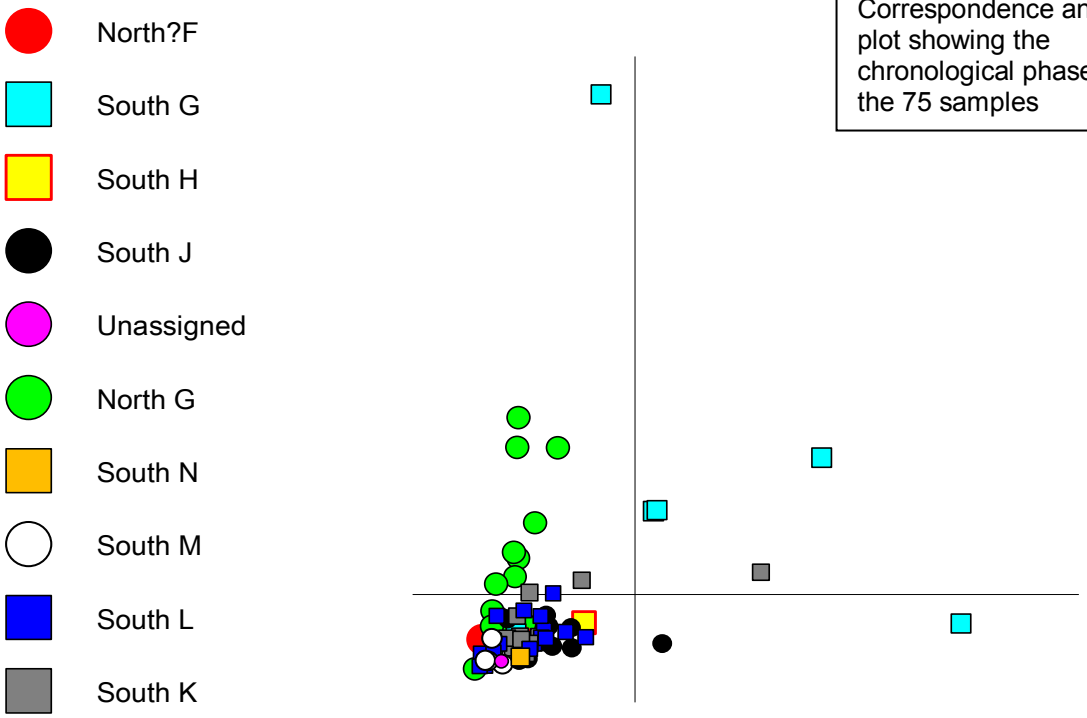
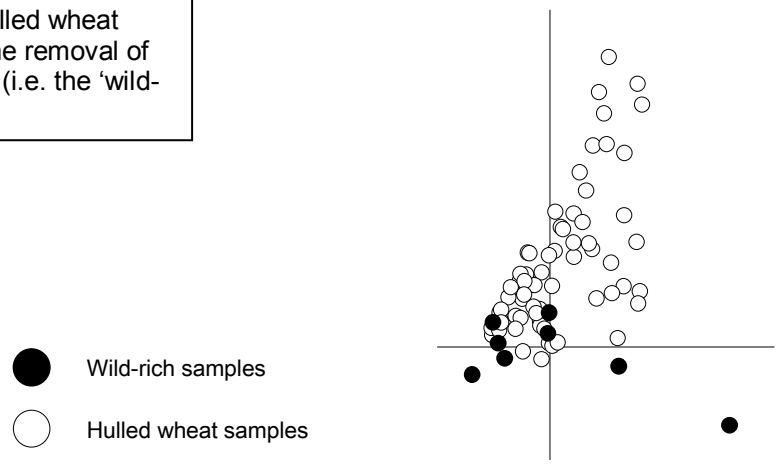


Figure 6.23
Correspondence analysis plot showing the chronological phases for the 75 samples

Figure 6.24
Correspondence analysis plot showing distribution of the wild-rich and hulled wheat samples after the removal of crop categories (i.e. the 'wild-only' analysis)



Figures 6.24-6.41 Axes	**1**	**2**	**3**	**4**	Total inertia
Eigenvalues	0.702	0.412	0.291	0.249	3.16
Cumulative percentage variance of species data	22.2	35.3	44.5	52.3	

Figure 6.25
Correspondence analysis species plot showing distribution of the dung-derived and other wild/weed taxa

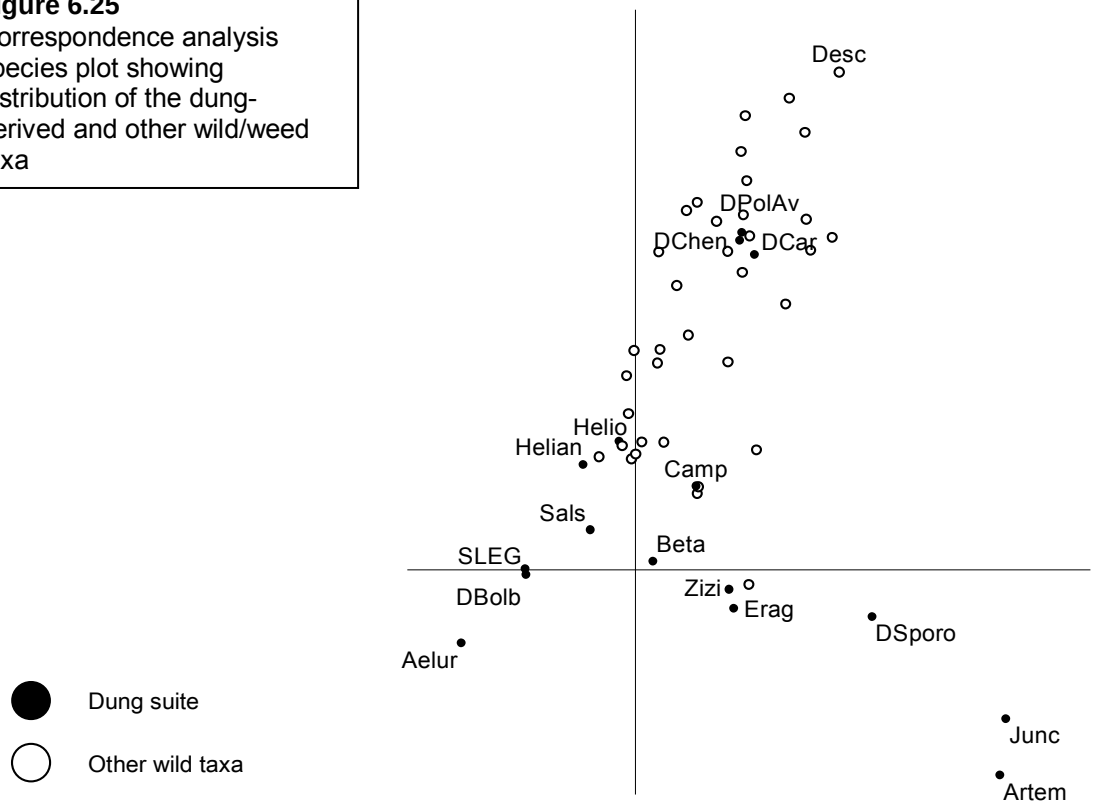


Figure 6.26
Correspondence analysis plot showing relative proportions of the dung-derived taxa, *Descurainia* and other wild/weed taxa

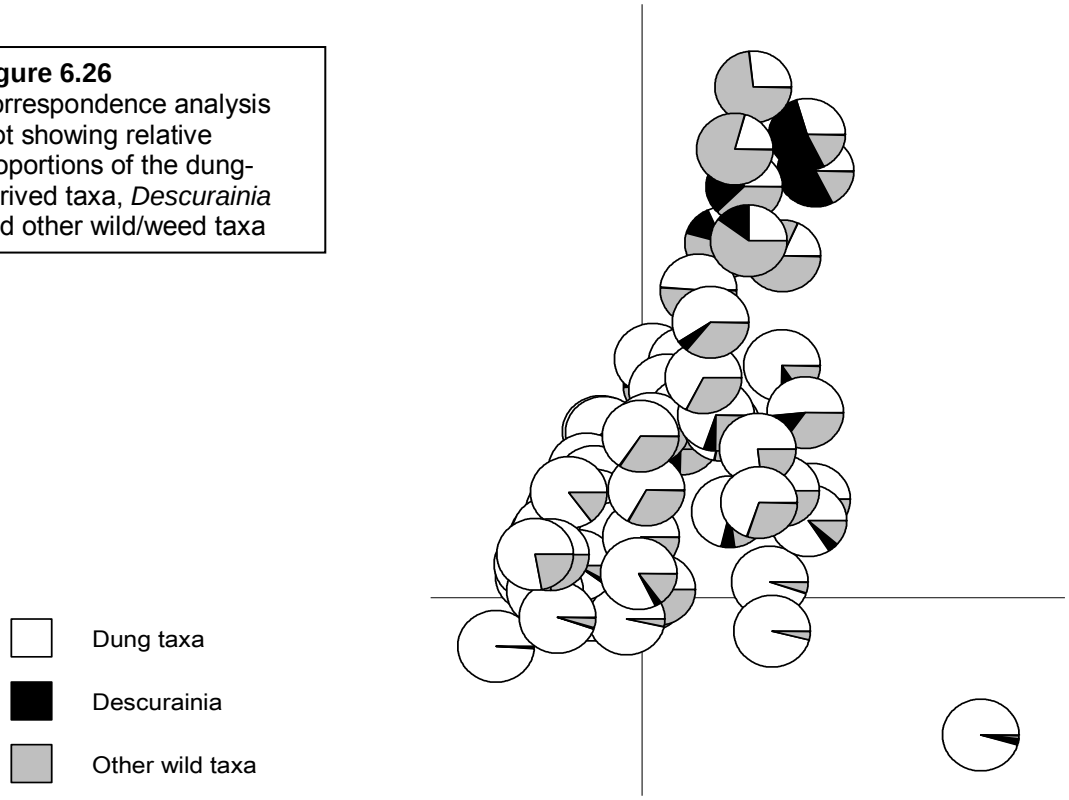


Figure 6.27
Correspondence analysis species plot showing distribution of the dung-derived taxa, *Descurainia* and other wild/weed taxa

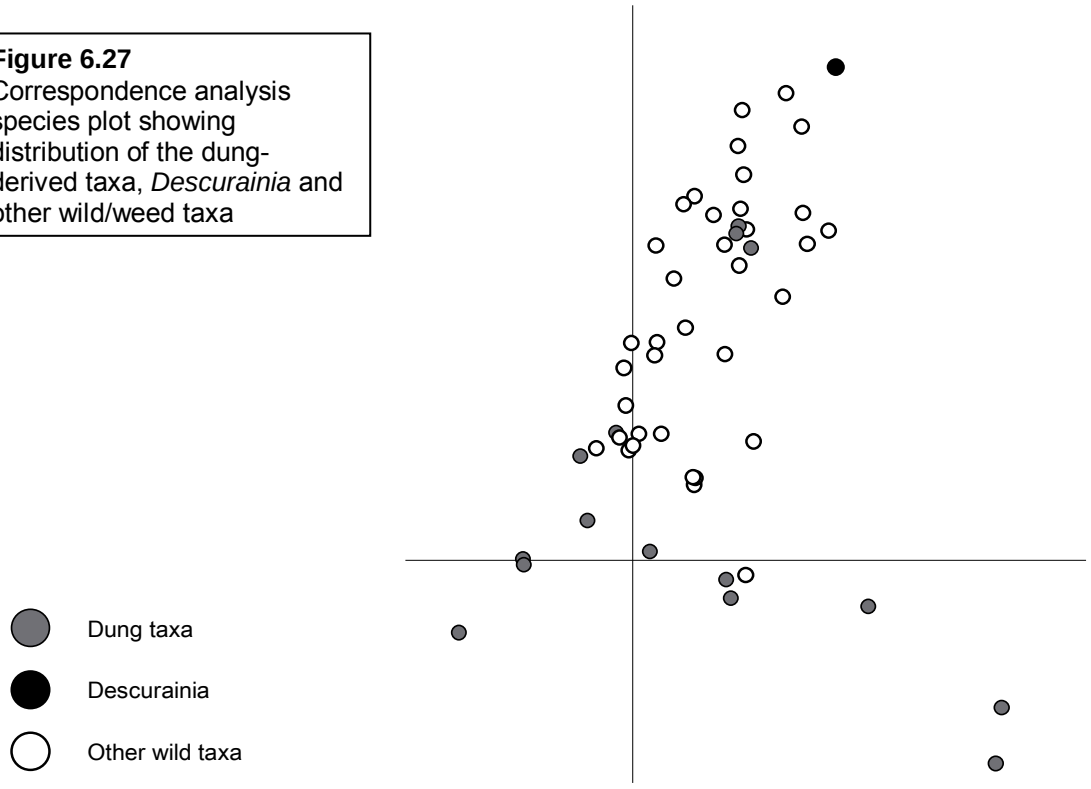


Figure 6.28
Correspondence analysis plot showing relative proportions of crop processing physical types of the wild/weed taxa

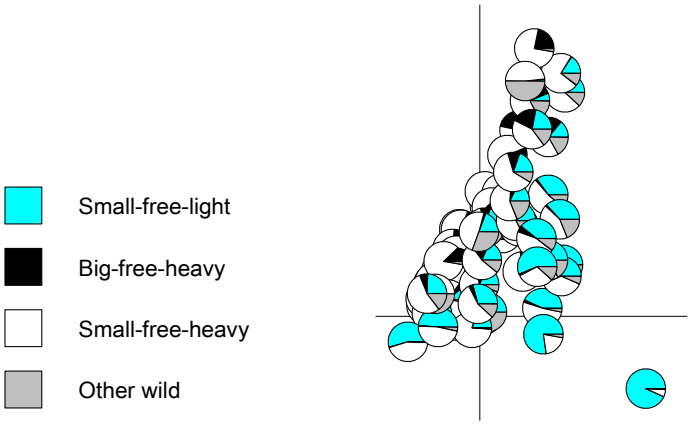


Figure 6.29
Correspondence analysis plot showing distribution of crop processing physical types of the wild/weed taxa

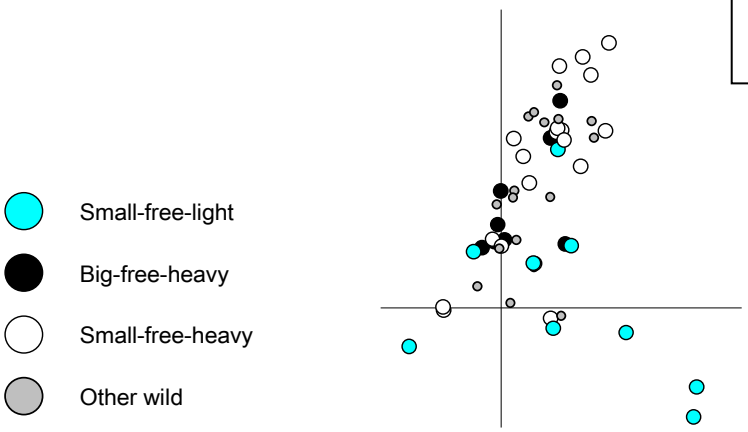
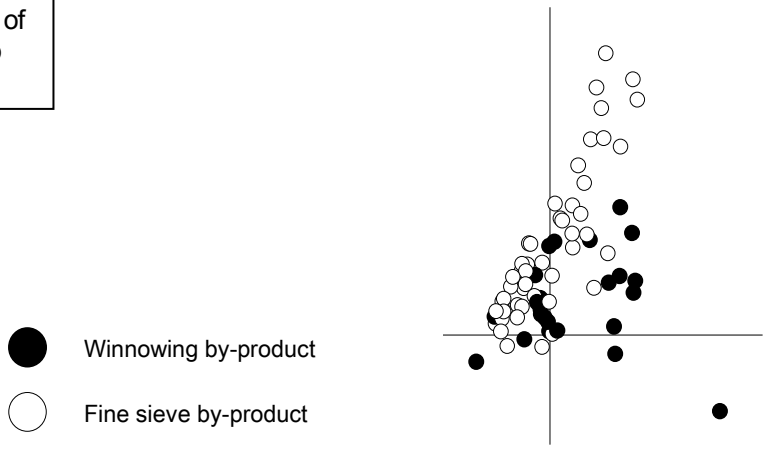


Figure 6.30
Correspondence analysis plot showing classification of the 75 samples in the crop processing analysis



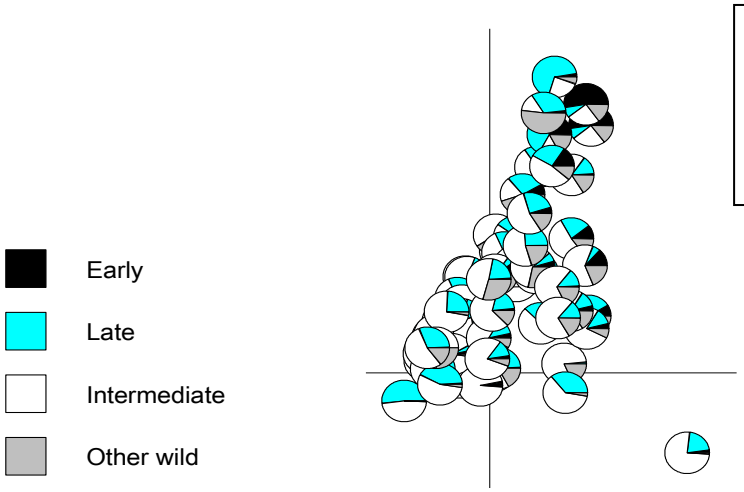
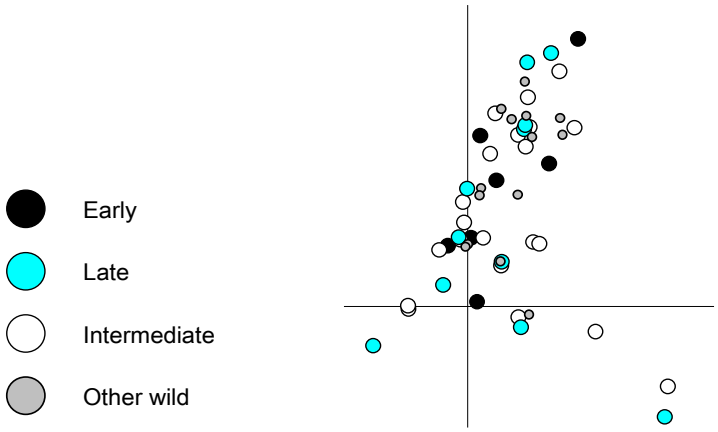


Figure 6.31
Correspondence analysis plot showing relative proportions of the seasonality (fruiting time) categories of the wild/weed taxa

Figure 6.32
Correspondence analysis plot showing distribution of the seasonality (fruiting time) categories of the wild/weed taxa



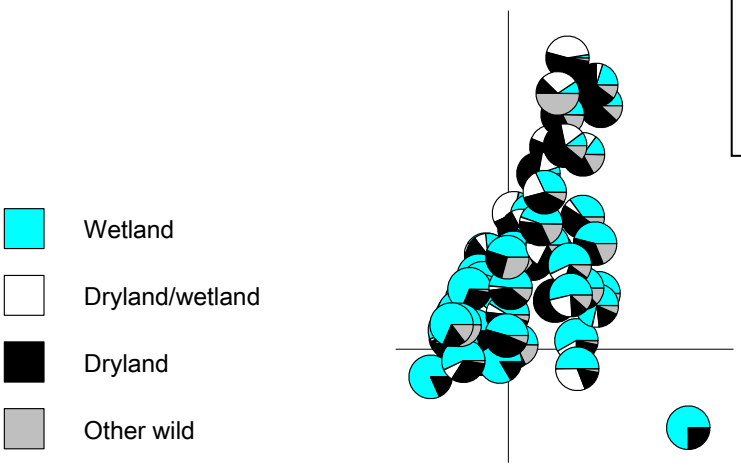


Figure 6.33
Correspondence analysis plot showing relative proportions of the habitat categories of the wild/weed taxa

Figure 6.34
Correspondence analysis plot showing distribution of the habitat categories of the wild/weed taxa

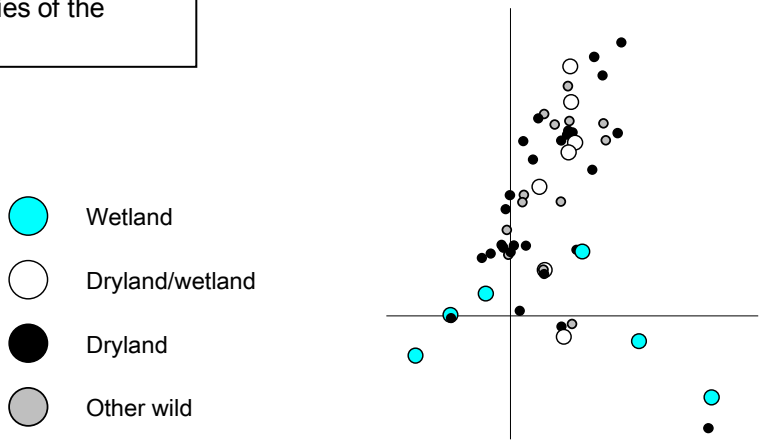


Figure 6.35
Correspondence analysis plot showing archaeological context types

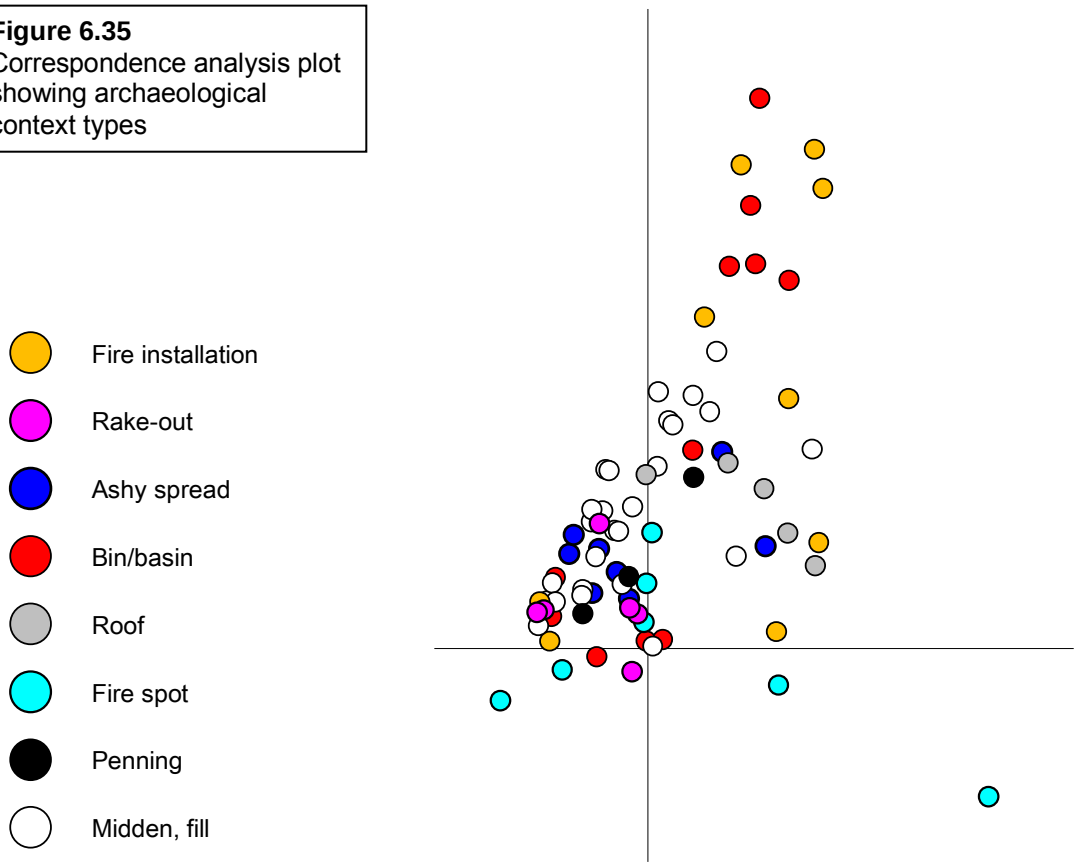


Figure 6.36
Correspondence analysis plot showing the depositional character (primary/secondary) of the samples

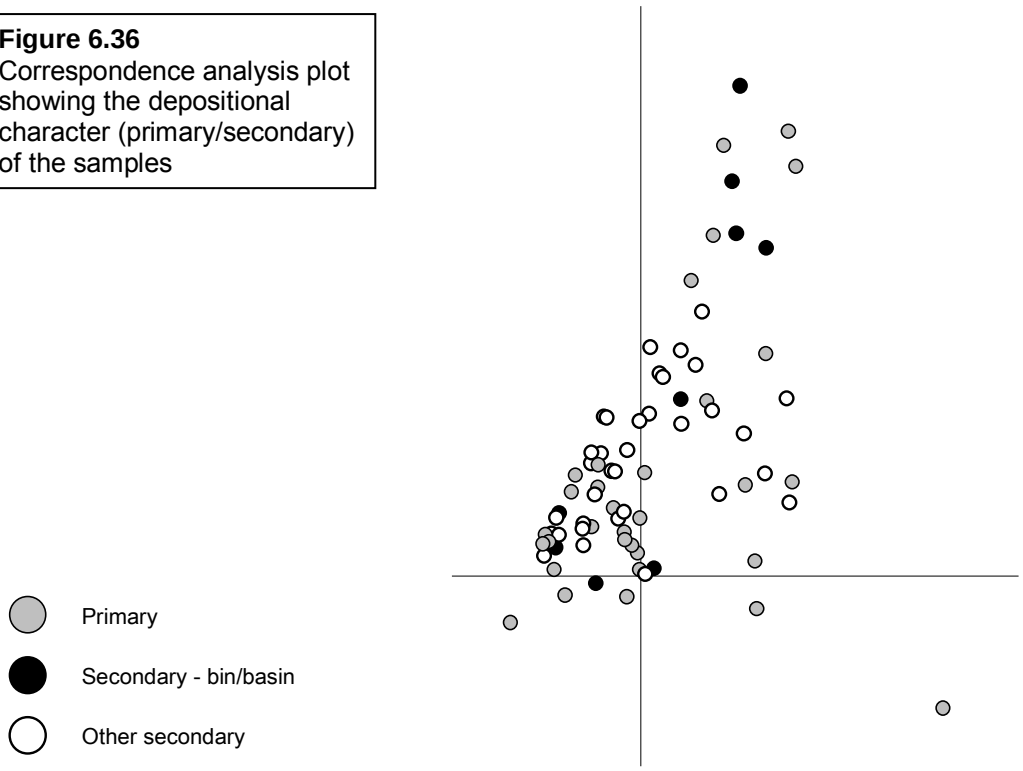


Figure 6.37
Correspondence analysis plot showing internal/external derivation of the samples ('location')

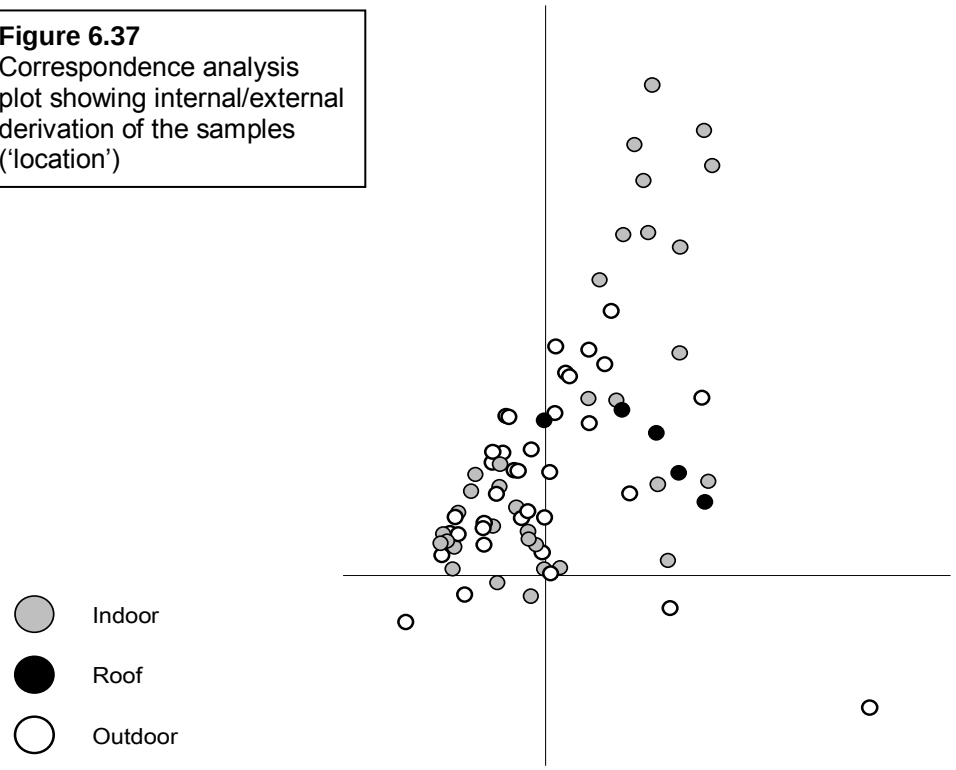


Figure 6.38
Correspondence analysis plot showing the depositional character and location of the samples

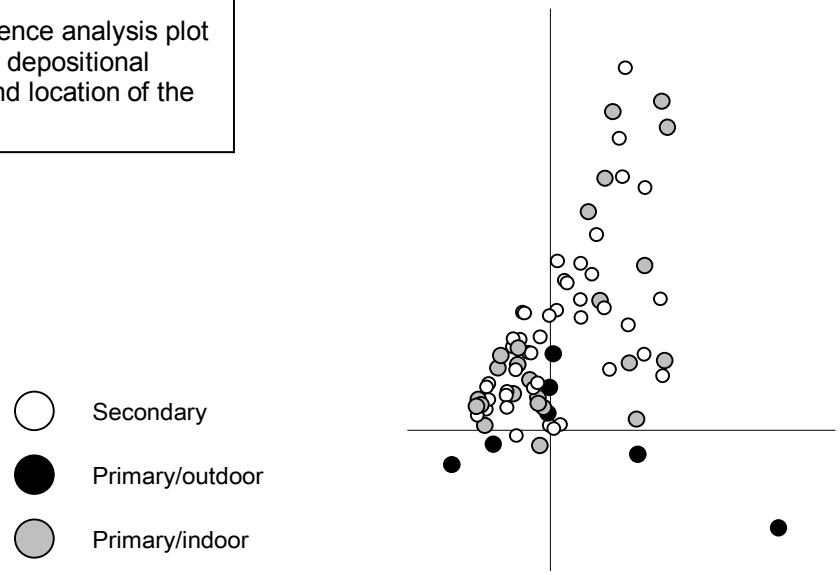


Figure 6.39
Correspondence analysis plot showing Building (B.) and Space (Sp.) derivation of the samples

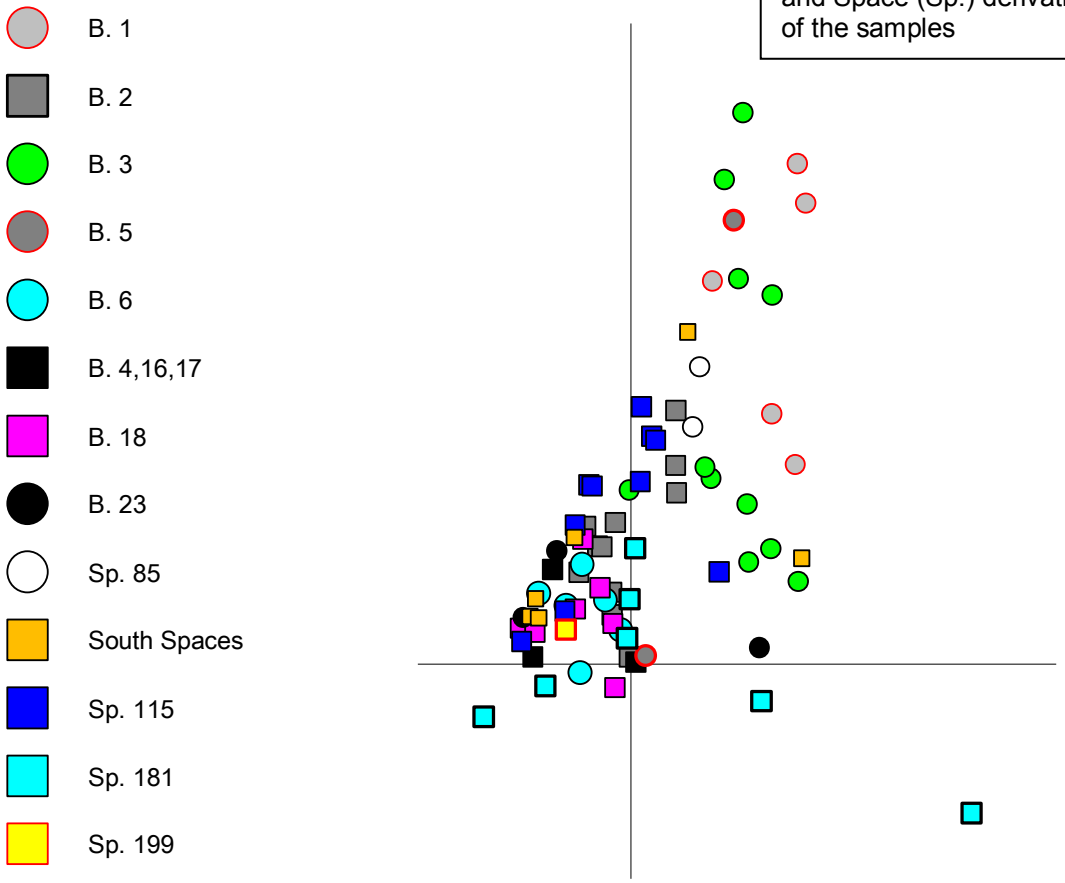


Figure 6.40
Correspondence analysis plot showing the excavation areas

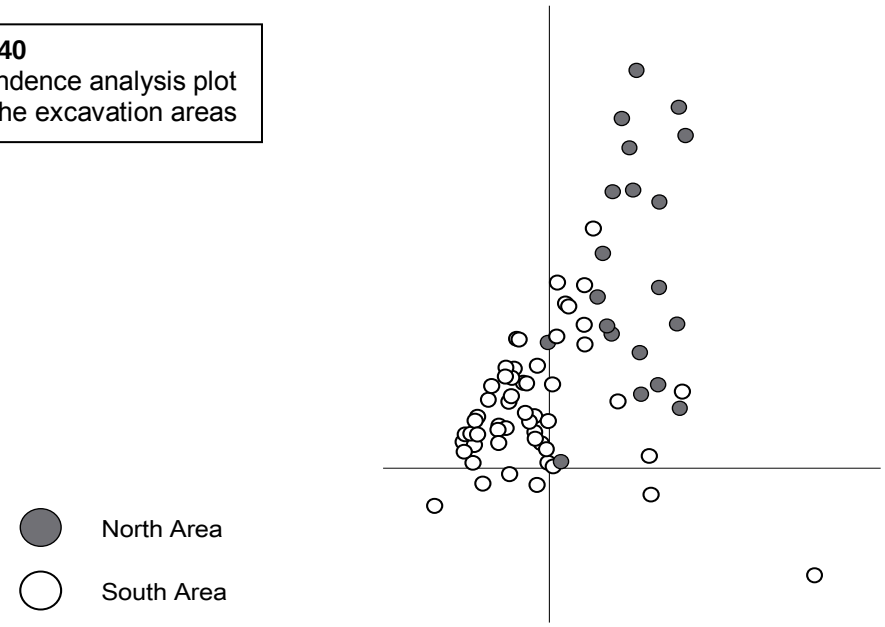


Figure 6.41
Correspondence analysis plot showing the chronological phases

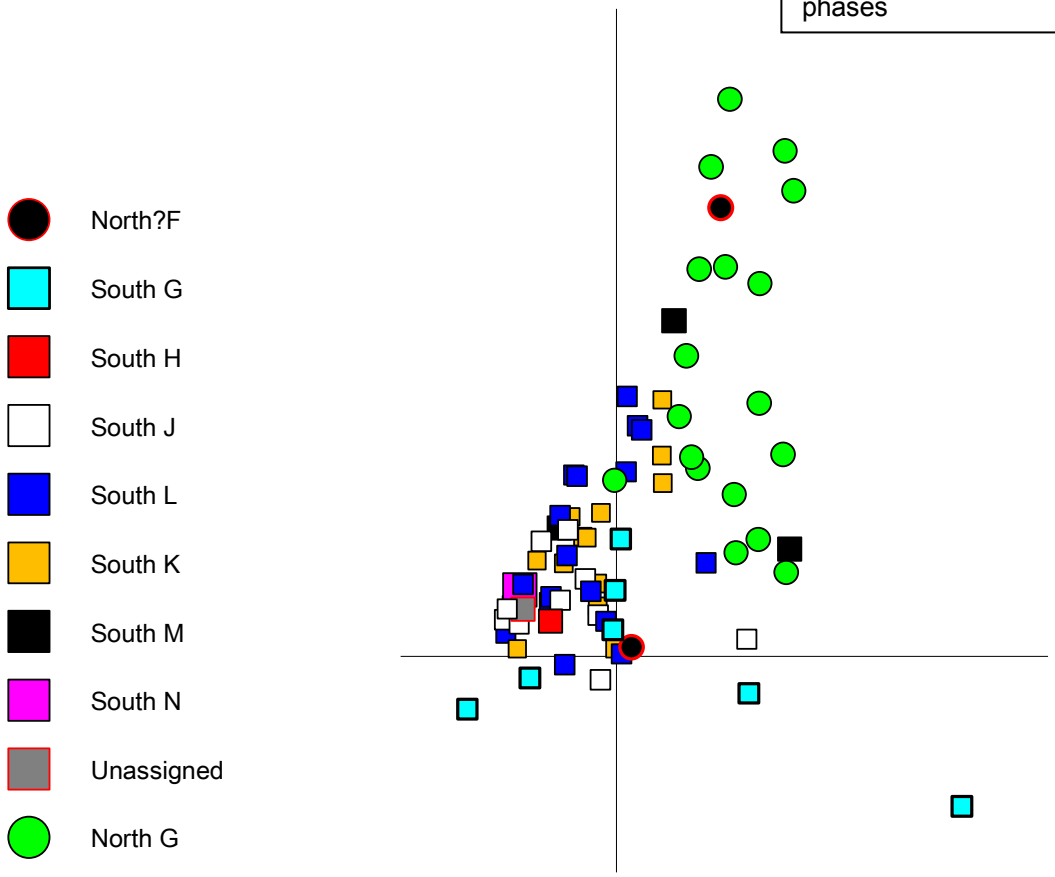
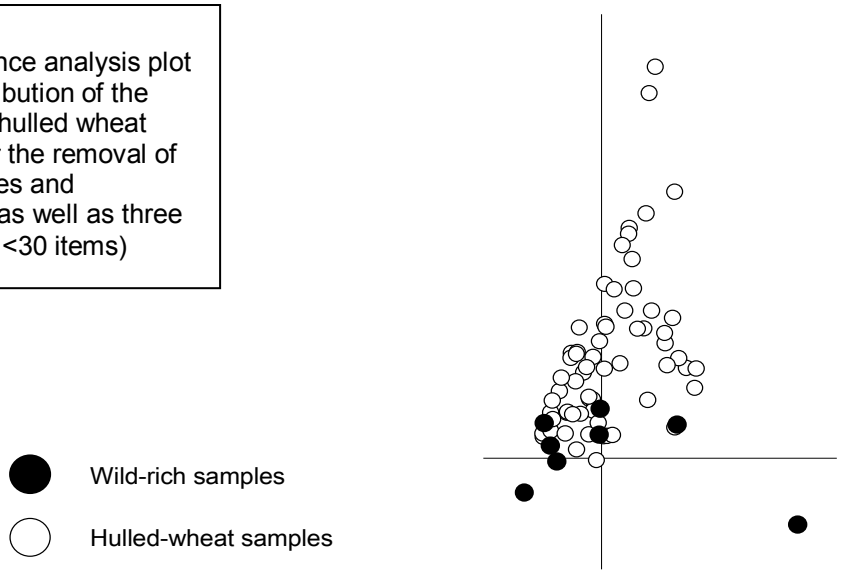
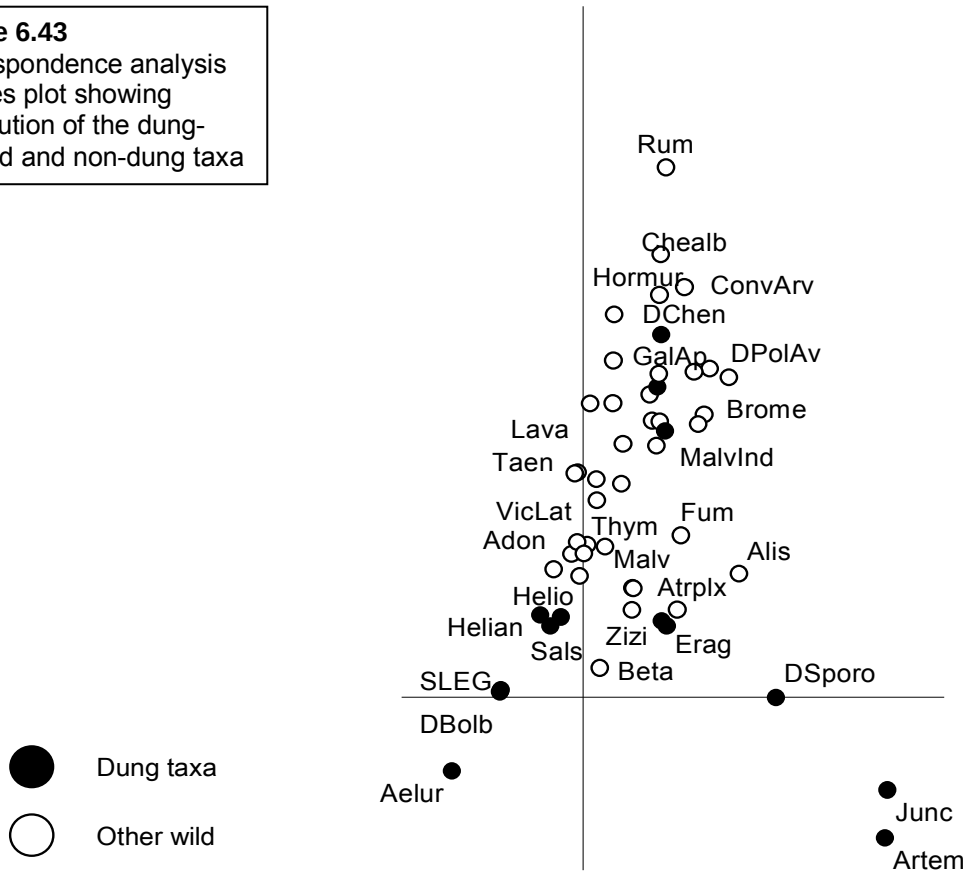


Figure 6.42
Correspondence analysis plot showing distribution of the wild-rich and hulled wheat samples after the removal of crop categories and *Descurainia* (as well as three samples with <30 items)



Figures 6.42-6.50 Axes	**1**	**2**	**3**	**4**	Total inertia
Eigenvalues	0.703	0.374	0.283	0.175	2.96
Cumulative percentage variance of species data	23.8	36.4	45.9	51.8	

Figure 6.43
Correspondence analysis species plot showing distribution of the dung-derived and non-dung taxa



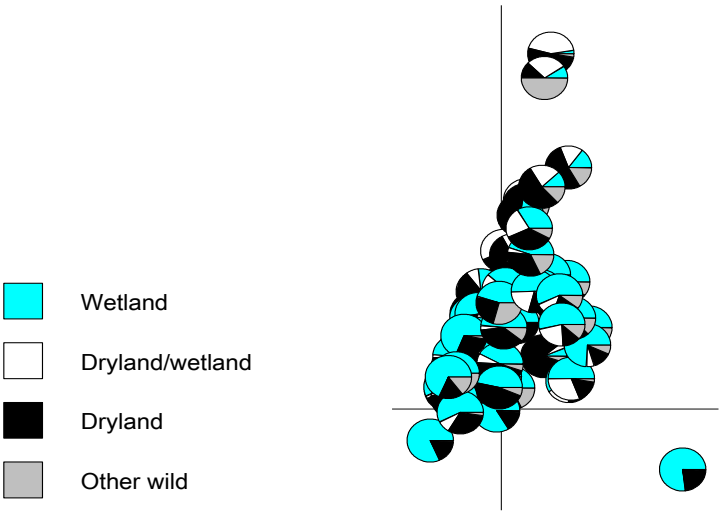
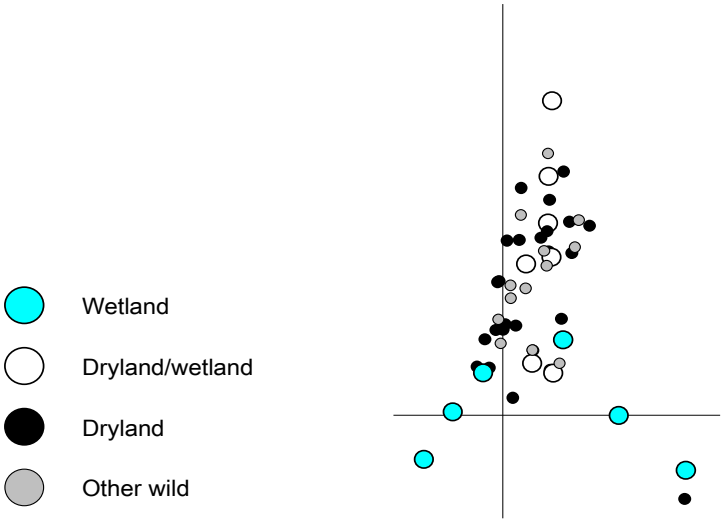


Figure 6.44
Correspondence analysis plot showing relative proportions of the habitat categories of the wild/weed taxa

Figure 6.45
Correspondence analysis species plot showing distribution of the the habitat categories of the wild/weed taxa



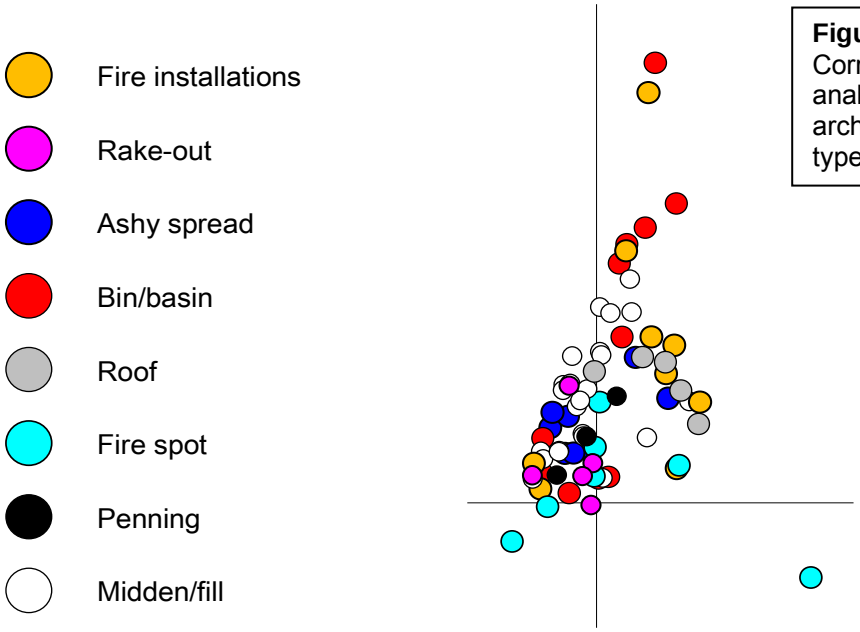


Figure 6.46
Correspondence analysis plot showing archaeological context types

Figure 6.47
Correspondence analysis plot showing the depositional character and location of the samples

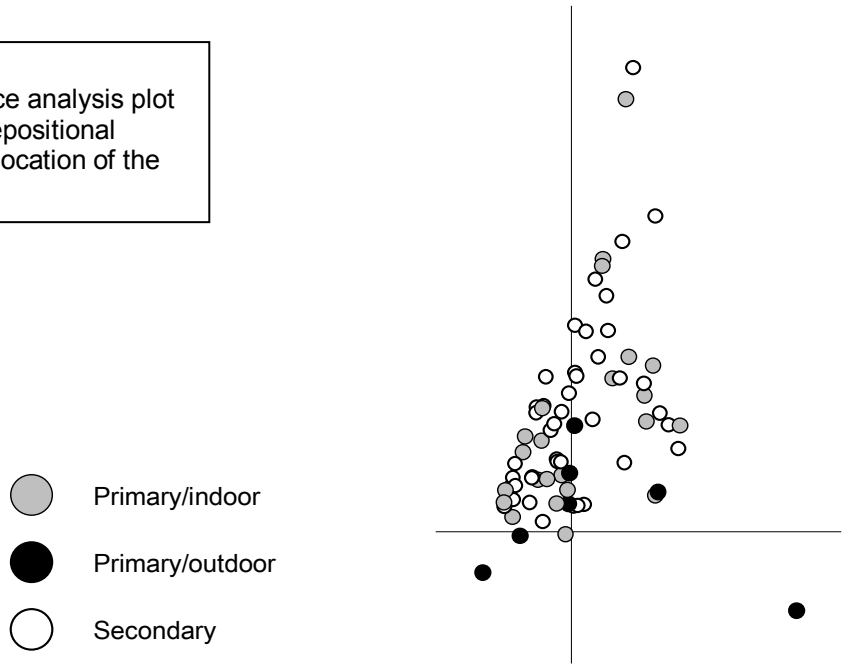


Figure 6.48
Correspondence analysis plot showing Building (B.) and Space (Sp.) derivation of the samples

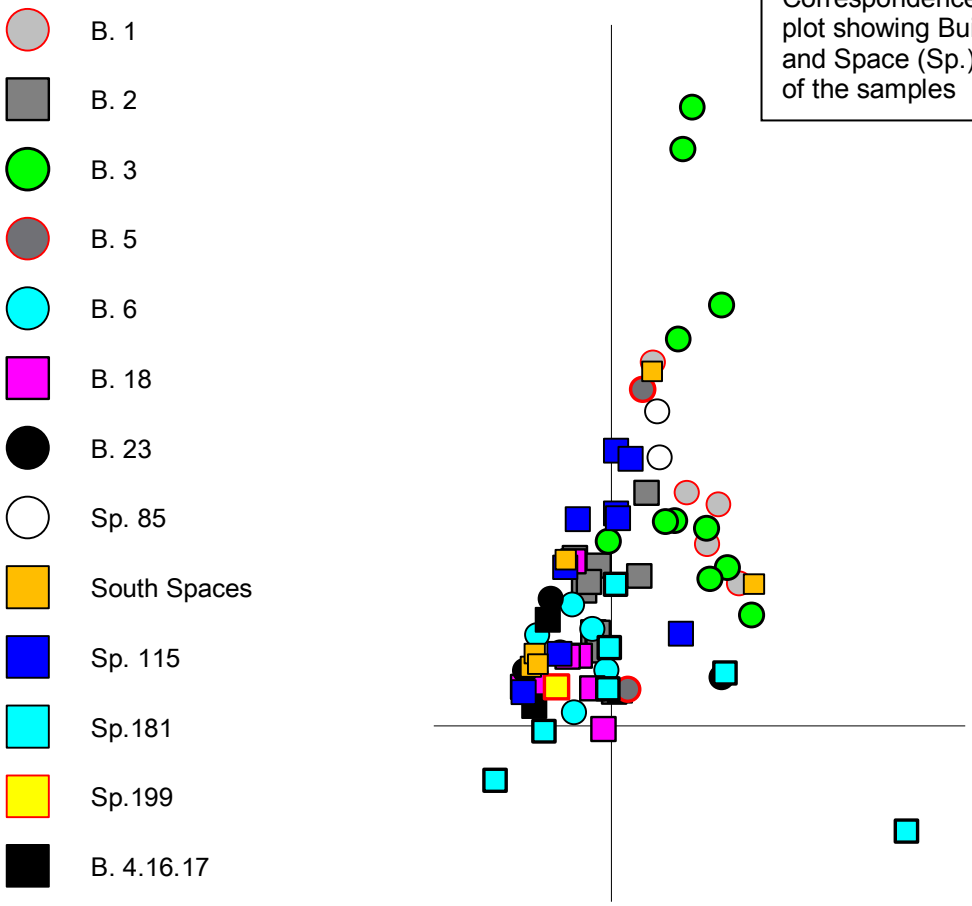


Figure 6.49
Correspondence analysis plot showing the excavation areas

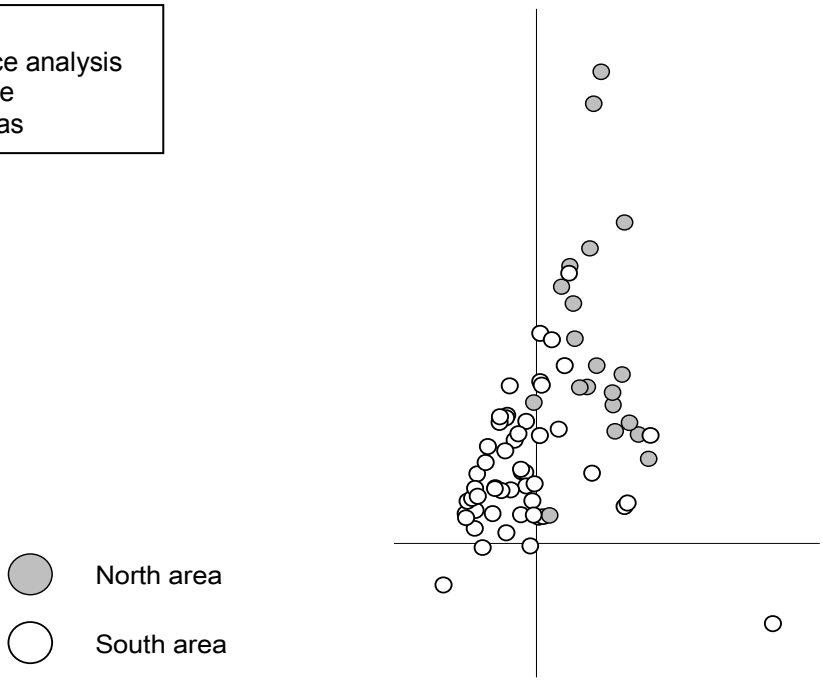
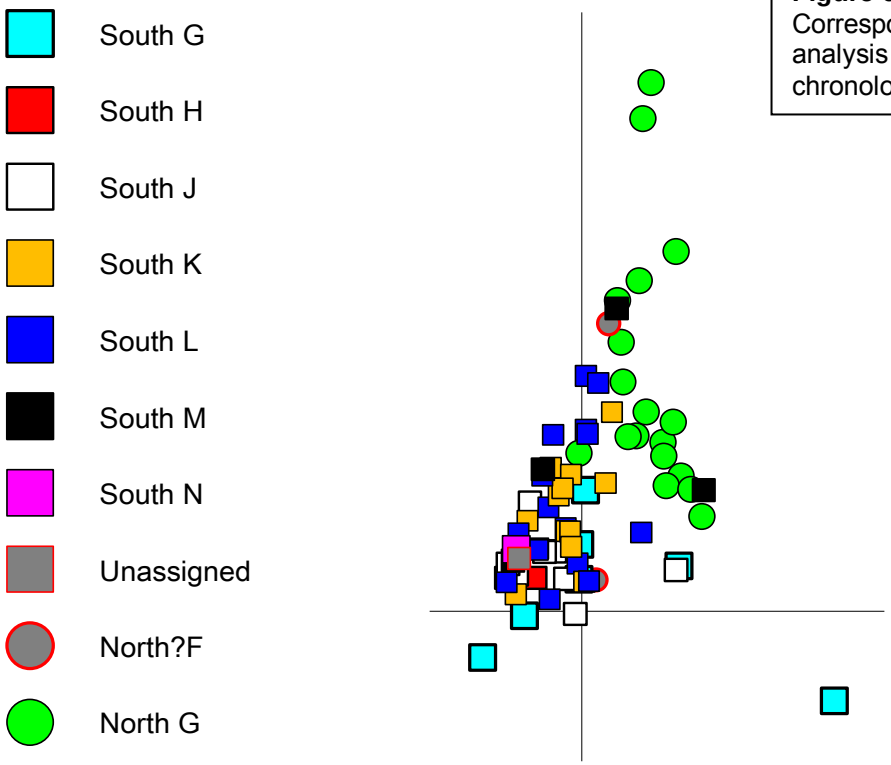


Figure 6.50
Correspondence analysis plot showing the chronological phases



	Sample number	*number of FIBS taxa*	*number of FIBS items*	Class	Probability		Chronology (area/phase)
					level	%	
1	150	*2*	12	field	high	0.992	North G
2	677	*2*	3	field	high	0.992	South L
3	366	*2*	4	field	high	1.000	South L
4	1010	*1*	2	field	high	0.967	South L
5	232	*1*	1	field	high	1.000	South M
6	588	*2*	12	field	low	0.504	South K
7	26-25.36	*2*	2	field	low	0.723	South J
8	395	**5**	29	garden	low	0.732	North G
9	74.103	**4**	12	garden	low	0.765	North G
10	173	**4**	7	garden	low	0.712	South L
11	2535	**3**	5	garden	low	0.617	South L
12	31-48.49.51	**7**	81	garden	low	0.809	South G
13	104	**6**	26	garden	high	0.999	North G
14	78	**5**	6	garden	high	1.000	North G
15	171.329	**5**	7	garden	high	1.000	North G
16	102	**5**	14	garden	high	1.000	North G
17	4732	**5**	23	garden	high	1.000	North G
18	4545.4626	**5**	24	garden	high	1.000	North G
19	16-31.49.64.1732	**5**	33	garden	high	1.000	North G
20	4741	**4**	9	garden	high	1.000	North G
21	4714	**4**	16	garden	high	1.000	North G
22	45	**4**	17	garden	high	0.978	North G
23	5030	**4**	26	garden	high	1.000	North G
24	520	**4**	59	garden	high	1.000	North G
25	1631	**3**	3	garden	high	1.000	North G
26	1795	**3**	4	garden	high	1.000	North G
27	3399	**3**	4	garden	high	1.000	North G
28	332	**3**	8	garden	high	0.998	North G
29	1853	**3**	9	garden	high	1.000	North G
30	282	**3**	11	garden	high	0.998	North G
31	535	**3**	13	garden	high	1.000	North G
32	516	**3**	18	garden	high	1.000	North G
33	1669	**3**	18	garden	high	1.000	North G
34	465	**3**	19	garden	high	0.997	North G
35	11	**3**	22	garden	high	0.997	North G
36	135	**3**	41	garden	high	1.000	North G
37	281	**3**	6	garden	high	0.998	South M
38	904	**3**	17	garden	high	1.000	South M
39	1297.164	**4**	69	garden	high	1.000	South L
40	295	**3**	5	garden	high	1.000	South L
41	2985	**3**	5	garden	high	0.921	South L
42	513	**3**	4	garden	high	0.987	South K
43	2326	**3**	5	garden	high	1.000	South K
44	1735	**3**	19	garden	high	1.000	South K
45	25-94.95.96	**4**	4	garden	high	1.000	South J
46	3546	**3**	10	garden	high	1.000	South J
47	31-04.06.07	**5**	16	garden	high	0.965	South H
48	31-27.33.37	**7**	151	garden	high	0.999	South G
49	3351	**5**	9	garden	high	0.996	South G
50	3324	**4**	17	garden	high	0.998	South G
51	3297	**4**	42	garden	high	1.000	South G
52	3742	**3**	7	garden	high	1.000	South G

Table 7.6 Results of the discriminant analysis showing the classification of samples as gardens or fields with high or low probability

	Sample number	*number of FIBS taxa*	*number of FIBS items*	Class	Probability		Chronology (area/phase)
					level	%	
53	345	*2*	2	garden	high	1.000	North G
54	539.551	*2*	2	garden	high	1.000	North G
55	4361	*2*	3	garden	high	1.000	North G
56	5019	*2*	3	garden	high	1.000	North G
57	23	*2*	4	garden	high	1.000	North G
58	101	*2*	4	garden	high	1.000	North G
59	144	*2*	76	garden	high	1.000	North G
60	87	*1*	1	garden	high	1.000	North G
61	1579	*1*	1	garden	high	1.000	North G
62	515	*1*	2	garden	high	0.947	North G
63	192	*1*	3	garden	high	0.966	North G
64	1950	*2*	2	garden	high	1.000	North F?
65	1791	*1*	13	garden	high	0.966	North F?
66	2439	*2*	2	garden	high	0.958	South N?
67	940	*1*	3	garden	high	0.966	South M
68	3099	*2*	2	garden	high	1.000	South L
69	1804	*1*	1	garden	high	0.966	South L
70	2425	*1*	2	garden	high	0.966	South L
71	2763	*1*	2	garden	high	0.966	South L
72	1038	*1*	9	garden	high	0.966	South L
73	2792	*1*	9	garden	high	0.966	South L
74	128	*1*	17	garden	high	0.966	South L
75	3247	*2*	30	garden	high	1.000	South K
76	830	*1*	1	garden	high	0.966	South K
77	2474	*1*	1	garden	high	0.966	South K
78	813	*1*	2	garden	high	0.966	South K
79	674	*1*	5	garden	high	0.966	South K
80	1156	*1*	11	garden	high	0.966	South K
81	639	*1*	14	garden	high	0.966	South K
82	27-13.15	*2*	5	garden	high	0.918	South J
83	26-37.38	*1*	1	garden	high	0.966	South J
84	3026	*1*	9	garden	high	0.966	South J
85	2679	*1*	1	garden	low	0.812	South J

Table 7.6 - *continued* Results of the discriminant analysis showing the classification of samples as gardens or fields with high or low probability

Bibliography

Ağcabay, M., A. Bogaard, M. Charles, G. Jones and N. Stone 2003 Macro botanical remains. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2003 Archive Report*. Online at http://www.catalhoyuk.com.

Akeret, Ö. and S. Jacomet 1997 Analysis of Plant Macrofossils in Goat/Sheep Faeces from the Neolithic lake Shore Settlement of Horgen Scheller – and Indication of Prehistoric Transhumance? *Vegetation History and Archaeobotany* 6: 235-239.

Akeret, Ö., J-N. Haas, U. Leuzinger and S. Jacomet 1999 Plant macrofossis and pollen in goat/sheep faeces from the Neolithic lake-shore settlement Arbon Bleiche 3, Switzerland. *The Holocene* 9: 175–182.

Akeret, Ö. and P. Rentzel 2001 Micromorphology and plant macrofossil analysis of cattle dung from the neolithic lake shore settlement of Arbon-Bleiche 3. *Geoarchaeology* 16: 687–700.

Anderberg, A-L. 1994 *Atlas of Seeds and Small Fruits of Northwest-European Plant Species, with Morphological Descriptions*. Part 4: *Resedaceae-Umbelliferae*. Stockholm: Swedish Museum of Natural History.

Anderson, S. and F. Ertuğ-Yaraş 1998 Fuel, fodder and faeces: An ethnographic and botanical study of dung fuel use in Central Anatolia. *Environmental Archaeology* 1: 99-109.

Anderson, P.C., L.S. Cummings, T.K. Schippers and B. Simonel (eds.) 2003 *Le Traitement des Récoltes. Un regard sur la diversité du Néolithique au present*. Actes des XXIIIe rencontres Internationales d'archéologie et d'histoire d'Antibes, Éditions APDCA.

Andrews, P., T. Molleson and B. Boz 2005 The Human Burials at Çatalhöyük. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*, Çatalhöyük Project Vol. 4, pp. 261-278. Cambridge: Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Arbuckle, B. 2008 Caprine exploitation at Erbaba Höyük: a Pottery Neolithic village in Central Anatolia. In E. Vila, L. Gourichon, A. Choyke and H. Buitenhuis (eds.) *Archaeozoology of the Near East VIII*, pp. 345-365. Lyon: Maison de l'Orient et de la Méditerrrané.

Arbuckle B., A. Öztan and S. Gülçur S. 2009 The evolution of sheep and goat husbandry in Central Anatolia. *Anthropozoologica* 44: 129-157.

Arnoldussen, S. 2008 A living landscape. Bronze Age settlement sites in the Dutch river area (c. 2000-800 BC). *Leiden: Sidestone Press.*

Askew, A.P., D. Corker, D.J. Hodkinson and K. Thompson 1997 A New Apparatus to Measure the Rate of Fall of Seeds. *Functional Ecology* 11: 121-125.

Asouti, E., A. Erkal, A. Fairbairn, C. Hastorf, A. Kennedy, J. Near and A.M. Rosen 1999 Archaeobotany and Related Plant Studies. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1999 Archive Report*. Online at http://www.catalhoyuk.com.

Asouti, E. and J. Hather 2001 Charcoal analysis and the reconstruction of ancient woodland vegetation in the Konya Basin, south-central Anatolia, Turkey: results from the Neolithic site of Çatalhöyük East. *Vegetation History and Archaeobotany* 10: 23-32.

Asouti, E. and A. Fairbairn 2002 Subsistence economy in Central Anatolia during the Neolithic - the archaeobotanical evidence. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001, pp. 181-192. Istanbul: Ege Yayınları.

Asouti, E. 2003 Woodland vegetation and fuel exploitation at the prehistoric campsite of Pınarbaşı, south-central Anatolia, Turkey: the evidence from the wood charcoal macro-remains. *Journal of Archaeological Science* 30: 1185–1201.

Asouti, E. 2005a Group identity and the politics of dwelling at Neolithic Çatalhöyük. In I. Hodder (ed.) *Çatalhöyük Perspectives: Themes from the 1995-99 seasons*, Çatalhöyük Project Vol. 6, pp. 75-91. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Asouti, E. 2005b Woodland Vegetation and the Exploitation of Fuel and Timber at Neolithic Çatalhöyük: Report on the Wood Charcoal Macro-remains. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*, Çatalhöyük Project Vol. 4, pp. 213-258. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Asouti, E. 2006 Beyond the Pre-pottery Neolithic B interaction sphere. *Journal of World Prehistory* 20: 87-1126.

Asouti, E. in press/2013 Woodland vegetation, firewood management and woodcrafts at Neolithic Çatalhöyük. In I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Atalay, S. and C.A. Hastorf 2005 Foodways at Çatalhöyük. In I. Hodder (ed.) *Çatalhöyük perspectives: reports from the 1995-99 season*. Çatalhöyük Project Vol. 6, pp. 109-123. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Atalay, S. and C.A. Hastorf 2006 Food, meals and daily activities: The *habitus* of food practices at Neolithic Çatalhöyük. *American Antiquity* 71 (2): 283-319.

Baird, D. 2002 Early Holocene settlement in Central Anatolia: Problems and prospects as seen from the Konya Plain. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001, pp. 139-152. Istanbul: Ege Yayınları.

Baird, D. 2005 The History of Settlement and Social Landscapes in the Early Holocene in the Çatalhöyük area. In I. Hodder (ed.) *Çatalhöyük perspectives: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 6, pp. 55-74. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Baird, D. 2006 The Boncuklu Project: The origins of sedentism, cultivation and herding in central Anatolia. *Anatolian Archaeology* 12: 13-16.

Baird, D. 2007 The Boncuklu Project: The origins of sedentism, cultivation and herding in central Anatolia. *Anatolian Archaeology* 13: 14-17.

Baird, D. 2008 The Boncuklu Project: The origins of sedentism, cultivation and herding in central Anatolia. *Anatolian Archaeology* 14: 11-12.

Baird, D. 2009 The Boncuklu Project: Investigating the beginnings of agriculture, sedentism and herding in central Anatolia. *Anatolian Archaeology* 15: 9-10.

Baird, D. 2010 The Boncuklu Project: Investigating the beginnings of agriculture, sedentism and herding in central Anatolia. *Anatolian Archaeology* 16: 9-11.

Balter, M. 1998 Why settle down? The mystery of communities. *Science* 282: 1442-5.

Banning, E.B. 1998 The Neolithic Period - Triumphs of Architecture, Agriculture, and Art. *Near Eastern Archaeology* 61 (4): 188-237.

Banning, E.B. 2003 Housing Neolithic Farmers. *Near Eastern Archaeology* 66 (1): 4-21.

Bar-Yosef, O. and A. Belfer-Cohen 1989 The Levantine "PPNB" interaction sphere. In I. Hershkovitz (ed.) *People and Culture in Change*. Proceedings of the Second Symposium of Upper Palaeolithic, Mesolithic, and Neolithic Populations of Europe and the Mediterranean Basin, pp. 59-72. BAR International Series. Oxford: Archaeopress.

Bar-Yosef, O. and A. Belfer-Cohen 1991 From sedentary hunter-gatherers to territorial farmers. In S.A. Gregg (ed.) *Between Bands and States*, pp. 181-202. Carbondale: Center for Archaeological Investigations, Southern Illinois University Press.

Bar-Yosef and Meadow 1995 The Origins of Agriculture in the Near East. In T.D. Price and A.B. Gebauer (eds.) *Last Hunters, First Farmers: New Perspectives on the Prehistoric Transition to Agriculture*, pp. 39-94. Santa Fe: School of American Research Press.

Bar-Yosef, O. and A. Gopher (eds.) 1997 *An Early Neolithic Village in the Jordan Valley, Part I: The Archaeology of Netiv Hagdud*. American School of Prehistoric Research, Bulletin 43. Cambridge: Peabody Museum, Harvard University.

Baskin C.C. and J.M. Baskin 1998 *Seeds: Ecology, biogeography, and evolution of dormancy and germination.* San Diego (CA): Academic Press.

Baxter, M. 2003 *Statistics in Archaeology*. London: Arnold.

Bayliss, A. and S. Farid 2007 Interpreting Chronology at Çatalhöyük. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2007 Archive Report*. Online at http:// www.catalhoyuk.com.

Bayliss, A., S. Farid and T. Higham in press/2013 Time will tell: Practicing Bayesian chronological modelling on the East Mound. In I. Hodder (ed.) *Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Behre, K.-E. and S. Jacomet 1991 The Ecological Interpretation of Archaeobotanical Data. In W. van Zeist, K. Wasylikowa and K.-E. Behre (eds.) *Progress in Old World Palaeoethnobotany*, 81-108. Rotterdam: Balkema.

Behre, K.E. 2008 Collected seeds and fruits from herbs as prehistoric food. *Vegetation History and Archaeobotany* 17: 65-73.

Berggren, G. 1969 *Atlas of seeds and small fruits of northwest-European plant species with morphological descriptions*, Part 2. Stockholm: Swedish Museum of Natural History.

Berggren, G. 1981 *Atlas of Seeds and Small Fruits of Northwest-European Plant Species, with Morphological Descriptions*, Part 3: *Salicaceae-Cruciferae*. Stockholm: Swedish Natural Science Research Council.

Black, M., J.D. Bewley and P. Halmer 2006 *The Encyclopedia of Seeds: Science, Technology and Uses*. Wallingford: CABI.

Biçakçi, E. 2003 Observations on the Early Pre-Pottery Neolithic architecture in the Near East: 1. New building materials and construction techniques. In M. Özdoğan, H. Hauptmann and N. Başgelen (eds.) *Köyden Kente. Yakındoğu'da Ilk Yerleşimler. From Villages to Cities. Early Villages in the Near East* (vol.1-2). Studies Presented to Ufuk Esin, pp. 385-413. Istanbul: Arkeoloji ve Sanat Yayınları.

Boardman, S. and G. Jones 1990 Experiments on the effects of charring on cereal plant components. *Journal of Archaeological Science* 17: 1-11.

Bogaard, A., C. Palmer, G. Jones, M. Charles and J.G. Hodgson 1999 A FIBS approach to the use of weed ecology in the archaeobotanical recognition of crop rotation. *Journal of Archaeological Science* 26: 1211–1224.

Bogaard, A., Charles, M., Halstead, P. and Jones, G. 2000 The Scale and Intensity of Cultivation: Evidence from Weed Ecology. In P. Halstead and Frederick, C. (eds.) *Landscape and Land Use in Postglacial Greece*, pp. 129-134. Sheffield: Sheffield Academic Press.

Bogaard, A., G. Jones, M. Charles and J.G. Hodgson 2001 On the Archaeobotanical Inference of Crop Sowing Time Using the FIBS Method. *Journal of Archaeological Science* 28: 1171-1183.

Bogaard, A. 2002 Questioning the Relevance of Shifting Cultivation to Neolithic Farming in the Loess Belt of Western-Central Europe: Evidence from the Hambach Forest Experiment. *Vegetation History and Archaeobotany* 11: 155-168.

Bogaard, A. 2004a *Neolithic Farming in Central Europe. An archaeobotanical study of crop husbandry practices*. London: Routledge.

Bogaard, A. 2004b The nature of early farming in central and south-east Europe. *Documenta Praehistorica* 31: 49–58.

Bogaard A., M. Charles, D. Filipovic, G. Jones and N. Stone 2004 Macro Botanical Remains. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2004 Archive Report*. Online at http://www.catalhoyuk.com.

Bogaard, A. 2005 'Garden agriculture' and the nature of early farming in Europe and the Near East. *World Archaeology* 37: 177-196.

Bogaard A., M. Charles, M. Ergun, G. Jones, K. Ng, M. Polcyn and N. Stone 2005a Macro Botanical Remains. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2005 Archive Report*. Online at http://www.catalhoyuk.com.

Bogaard, A., G. Jones and M. Charles 2005b The impact of crop processing on the reconstruction of crop sowing time and cultivation intensity from archaeobotanical weed evidence. *Vegetation History and Archaeobotany* 14: 505–509.

Bogaard A., M. Charles, M. Ergun, G. Jones, K. Ng, M. Polcyn and N. Stone 2006 Macro Botanical Remains. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2006 Archive Report*. Online at http://www.catalhoyuk.com.

Bogaard A., M. Charles, F. Ertuğ, D. Filipovic, C. Longford, and M. Wallace 2007 Macro Botanical Remains. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2007 Archive Report*. Online at http://www.catalhoyuk.com.

Bogaard A., M. Charles, M. Ergun, F. Ertuğ and D. Filipovic 2008 Macro Botanical Remains 2008. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2008 Archive Report*. Online at http://www.catalhoyuk.com.

Bogaard, A., M.P. Charles, K.C. Twiss, A.S. Fairbairn, E.N. Yalman, D. Filipovic, G.A. Demirergi, F. Ertuğ, N. Russell and J. Henecke 2009 Private pantries and celebrated surplus: Saving and sharing food at Neolithic Çatalhöyük, central Anatolia. *Antiquity* 83: 649–668.

Bogaard, A., J. Bending and G. Jones 2007 Archaeobotanical evidence for plant husbandry and use. In A. Whittle *The Early Neolithic on the Great Hungarian Plain. Investigations of the Körös culture site of Ecsegfalva 23, County Békés*, pp. 421-446. Varia Archaeologica Hungarica, Vol. II. Budapest: Archaeological Institute of the Hungarian Academy of Sciences.

Bogaard, A. and V. Isaakidou 2010 From Megasites to Farmsteads: Community Size, Ideology and the Nature of Early Farming Landscapes in Western Asia and Europe. In Finlayson, B. and G. Warren (eds.) *Landscapes in Transition*, pp. 192-207. Oxford: Oxbow.

Bogaard, A. 2012 *Plant Use and Crop Husbandry in an Early Neolithic Village: Vaihingen an der Enz, Baden-Württemberg*. Frankfurter Archäologische Schriften. Bonn: Habelt-Verlag.

Bogaard, A., M. Charles, A. Livarda, M. Ergun, D. Filipovic, G. Jones in press/2013 The archaeobotany of mid-later Neolithic Çatalhöyük. In I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Bogucki, P. 1996 The spread of early farming in Europe. *American Scientist* 84: 242-253.

Bogucki, P. 1999 *The Origins of Human Society*. Oxford: Blackwell.

Bordaz, J. 1973 Current research in the Neolithic of South central Turkey: Süberde, Erbaba and the chronological implications. *American Journal of Archaeology* 77: 282-288.

Bordaz, J. and L.A. Bordaz 1978 Erbaba, 1977. *Anatolian Studies* 28: 20-21.

Bottema, S. 1984 The composition of modern charred seed assemblages. In W.A. Casparie and W. van Zeist (eds.) *Plants and Ancient Man*: *Studies in palaeoethnobotany*, pp. 207-212. Rotterdam: Balkema.

Bottema S. and H. Woldring 1984. Late quaternary vegetation and climate of southwestern Turkey.Part II. *Paleohistoria* 26: 123-149.

Bowman, A.R.A. 1966 Studies on the heat induced carbonisation of cereal grains. Unpublished undergraduate dissertation. Department of Agricultural Botany, University of Reading. Cited in Boardman, S. and G. Jones 1990 Experiments on the effects of charring on cereal plant components. *Journal of Archaeological Science* 17: 1-11.

Boyer, P. 1999 *A geoarchaeological approach to Late Quaternary environmental change in South Central Turkey*. Unpublished PhD dissertation. Loughborough University, Leicestershire, UK.

Boyer, P., N. Roberts and D. Baird 2006 Holocene Environment and Settlement on the Çarşamba Alluvial Fan, South-Central Turkey: Integrating Geoarchaeology and Archaeological Field Survey. *Geoarchaeology* 21 (7): 675-698.

Braadbaart, F. 2004 *Carbonization of peas and wheat*. A laboratory study Leiden, The Netherlands. Online at: www.amolf.nl.

Braadbaart, F. 2008 Carbonisation and morphological changes in modern dehusked and husked *Triticum dicoccum* and *Triticum aestivum* grains. *Vegetation History and Archaeobotany* 17: 155–166.

Brochier, J.E. 1993 Çayönü tepesi: domestication, rythmes et environnement au PPNB. *Paléorient* 19: 39-49.

Brown, A.G. 1997 *Alluvial geoarchaeology: floodplain archaeology and environmental change*. Cambridge: Cambridge University Press.

Bryson, R.A. and R.U. Bryson 1999 Holocene Climates of Anatolia: as Simulated with Archaeoclimatic Models. *TÜBA-AR* II: 1-13.

Buitenhuis, H. 1997 Aşıklı Höyük: a "protodomestication" site. *Anthropozoologica* 25–26: 655–662.

Buitenhuis, H. 2002 Two annotated charts of the archaeozoological research. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC,* Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001, pp. 217-218. Istanbul: Ege Yayınları.

Butler, A. 1992 Pulse agronomy: traditional systems and implications for early cultivation, In P.C. Anderson (ed.) *Pre´histoire de L'Agriculture: Nouvelles Approches Expérimentales et Ethnographiques*, pp. 67-78. Paris: Éditions du CNRS.

Butler, A. 1995 The Plant Remains. Preliminary Report 1995. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1995 Archive Report*. Online at http://www.catalhoyuk.com**.**

Butler, A., Z. Tesfay, C. D'Andrea and D. Lyons 1999 The ethnobotany of *Lathyrus sativus* L. in the highlands of Ethiopia. In M. van der Veen (ed.) *The Exploitation of Plant Resources in Ancient Africa*, pp. 123-136. New York: Kluwer/Plenum.

Byrd, B.F. 1994 Public and private, domestic and corporate: the emergence of the Southwest Asian village. *American Antiquity* 59 (4): 639-666.

Byrd, B.F. 2000 Households in Transition. Neolithic Social Organization within Southwest Asia. In I. Kuijt (ed.) *Life in Neolithic farming communities; social organisation, identity and differentiation*, pp. 92-102. New York: Kluwer Academic.

Byrd, B.F. 2005a *Early Village Life at Beidha, Jordan: Neolithic Spatial Organization and Vernacular Architecture: The Excavations of Mrs. Diana Kirkbride-Helbæk.* New York: Oxford University Press.

Byrd, B.F. 2005b Reassessing the Emergence of Village Life in the Near East. *Journal of Archaeological Research* 13 (3): 231-290.

Cappers, R.T.J., R.M. Bekker and J.E.A. Jans 2006 (1st edition) *Digital Seed Atlas of the Netherlands.* Eelde: Barkhuis Publishing.

Cappers, R.T.J. and D.C.M. Raemaekers 2008 Cereal cultivation at Swifterbant? Neolithic Wetland Farming on the North European Plain. *Current Anthropology* 49 (3): 385-402.

Cane, R.M., R.Q. Cuthrell, M.P. Sayre, K.E. Soluri and C.A. Hastorf (with K. Killackey and S. Morell-Hart) 2012 Building 3's life through plant use: The macrobotanical evidence of Neolithic dwelling from the Berkeley Archaeology at Çatalhöyük (BACH) excavations 1997-2003. In R. Tringham and M. Stevanović (eds.) *Last House on the Hill: BACH Area Reports from Çatalhöyük, Turkey*. Los Angeles: Cotsen Institute of Archaeology Publications, University of California.

Carruthers, D. 2003 *Hunting and herding in Central Anatolian prehistory: the 9th and 7th millennium site at Pınarbaşı.* Unpublished PhD thesis. Department of Archaeology, Edinburgh University.

Carter, T., A. Spasojević and H. Underbjerg 2000 Chipped stone. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2000 Archive Report*. Online at http://www.catalhoyuk.com.

Carter, T., J. Conolly and A. Spasojević 2005 The chipped stone. In I. Hodder (ed) *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*. Catalhöyük Project Vol. 5, pp. 221-283. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Cauvin, J. 2000 *The Birth of the Gods and the Origins of Agriculture*. Cambridge: Cambridge University Press.

Cessford, C. 2001 A new dating sequence for Çatalhöyük. *Antiquity* 75: 717-725.

Cessford, C. 2005 Estimating the Neolithic Population of Çatalhöyük. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons.* Catalhöyük Project Vol. 4, pp. 323-326. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Cessford, C., M.W. Newton, P.I. Kuniholm, S.W. Manning, M. Ozbakan, A. Melek Ozer, K.G. Akoğlu, T. Higham and P. Blumbach 2005 Absolute dating at Çatalhöyük. In I. Hodder (ed.) *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 5, pp. 65-99. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Cessford, C. 2007a Level Pre-XII.E-A and Levels XII and XI, Spaces 181, 199,198**.** In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, pp. 59-101. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Cessford, C. 2007b Neolithic Excavations in the North Area, East Mound, Çatalhöyük 1995-98. In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, 345-549. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Cessford, C. 2007c (with contributions by A. Fairbairn, N. Russel and L. Martin) - *In situ* activities. In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, pp. 3-24. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Cessford, C. and S. Farid 2007 Excavation, recording and sampling methodologies. In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, pp. 3-24. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Charles, M., G. Jones and J.G. Hodgson 1997 FIBS in archaeobotany: functional interpretation of weed floras in relation to husbandry practices. *Journal of Archaeological Science* 24: 1151-1161.

Charles, M. 1998 Fodder from dung: The recognition and interpretation of dung-derived plant material from archaeological sites. *Environmental Archaeology* 1: 111-122.

Charles, M. and A. Bogaard 2001 Third-millenium BC Charred Plant Remains from Tell Brak. In Oates, D., J. Oates and H. McDonald (eds.) *Excavations at Tell Brak, Vol. 2: Nagar in the Third Millennium BC*, pp. 301-326. British School of Archaeology in Iraq.

Charles, M., A. Bogaard, G. Jones, J.G. Hodgson and P. Halstead 2002 Towards the archaeobotanical identification of intensive cereal cultivation: present-day ecological investigation in the mountains of Asturias, Northwest Spain. *Vegetation History and Archaeobotany* 11: 133-142.

Charles, M. and C. Hoppé 2003 The effects of irrigation on the weed floras of winter cereal crops in the Wadi Ibn Hamad (southern Jordan). *Levant* 35: 213-230.

Charles, M., C. Hoppé, A. Bogaard, G. Jones and J.G. Hodgson 2003 Using weed functional attributes for the identification of irrigation regimes in Jordan. *Journal of Archaeological Science* 30: 1429-1441.

Charles, M. and A. Bogaard 2005 Identifying livestock diet from charred plant remains: a Neolithic case study from southern Turkmenistan. In J. Davies, M. Fabiš, I. Mainland, M. Richards and R. Thomas (eds.) *Diet and health in past animal populations. Current research and future directions*, pp. 93-103. Oxford: Oxbow.

Charles, M. and A. Bogaard 2010 Charred plant macro remains from Jeitun: implications for early cultivation and herding practices in western Central Asia. In D.R. Harris (ed.) *Origins of Agriculture in western Central Asia: archaeological and environmental investigations in southern Turkmenistan*, pp. 150-165. Philadelphia: University of Pennsylvania Press.

Charles, M. C. Doherty, E. Asouti , A. Bogaard, E. Henton, K.C. Twiss and P. Ryan in press/2012 Landscape and Mobility. In I. Hodder (ed.) *Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Clarke, D. 1973 Archaeology: the loss of innocence. *Antiquity* 47: 6-18.

Colledge, S. 1998 Identifying pre-domestication cultivation using multivariate analysis. In V. Damania, J. Valkoun, G. Willcox and C.O. Qualset (eds.) *The Origins of Agriculture and Crop Domestication*, pp. 121-131. Aleppo: International Center for Agricultural Research in Dry Areas.

Colledge, S. 2001 *Plant exploitation on Epipalaeolithic and Early Neolithic sites in the Levant.* Oxford: BAR International Series.

Colledge, S. and J. Connolly (eds.) 2007 *The Origins and Spread of Domestic Plants in Southwest Asia and Europe.* UCL: Institute of Archaeology Publications.

de Contenson, H. 1971 Tell Ramad: a village of Syria of the 7th to 6th millennia B.C. *Archaeology* 24: 278–285.

de Contenson, H., P. Anderson, M-C. Cauvin, J. Clère, P. Ducos, M. Dupeyron, C. Maréchal and D. Stordeur 1995 *Aswad et Ghoraifé, sites néolithiques en Damascène (Syrie) aux IXe et VIIIe millénaires avant l'ère chrétienne*. Beyrouth: French Institute of the Archaeology of the Near East.

de Contenson, H., M-C. Cauvin, L. Courtois, P. Ducos, M. Dupeyron and W. van Zeist 2000 *Ramad: site Neolithique en Damascene (Syrie) aux VIIIe et VIIe millenaires avant l'ere Chretienne*. Beyrouth: French Institute of the Archaeology of the Near East.

Crawford, G. W., A. Underhill, Z. Zhao, G-A. Lee, G. Feinman, L. Nicholas, F. Luan, H. Yu, H. Fang and F. Cai 2005 Late Neolithic Plant Remains from Northern China: Preliminary Results from Liangchengzhen, Shandong. *Current Anthropology* 42 (2): 309-316.

Cutting, M. 2005 *The Neolithic and Early Chalcolithic Farmers of Central and Southwest Anatolia: Household, community and the changing use of space*. BAR International Series 1435. Oxford: Archaeopress.

Çilingiroğlu, A., Z. Derin, E. Abbay, H. Sağlamtimur and I. Kayan 2004 *Ulucak Höyük. Excavations Conducted Between 1995-2002*. Ancient Near Eastern Studies, Supplement 15. Louvain: Peeters.

D'Andrea, A.C. and H. Mitiku 2002 Traditional Emmer Processing in Highland Ethiopia. *Journal of Ethnobiology* 22 (2): 179-217.

Dallwitz, M.J. 1980 A general system for coding taxonomic descriptions. *Taxon* 29: 41–46. http://delta-intkey.com.

Dallwitz, M.J., T.A. Paine and E.J. Zurcher 1993 *User's guide to the DELTA system: a general system for processing taxonomic descriptions*, 4th edition. http://delta-intkey.com.

Davies, M.S. and G.C. Hillman 1988 Effects of Soil Flooding on Growth and Grain Yield of Populations of Tetraploid and Hexaploid Species of Wheat. *Annals of Botany* 62: 597-604.

Davis, P.H. (ed.) 1965–1985 *Flora of Turkey and the East Aegean Islands*. Vols. 1–9. Edinburgh: Edinburgh University Press. (Vol. 1 - 1965; Vol. 2 - 1967; Vol. 3 - 1970; Vol. 4 - 1972; Vol. 5 - 1975; Vol. 6 - 1978; Vol. 7 - 1982; Vol. 9 - 1985).

Davis, P.H., R.R. Mill and K. Tan 1988 *Flora of Turkey and the East Aegean Islands* (Supplement), Vol. 10. Edinburgh: Edinburgh University Press.

Dennell, R.W. 1972 The interpretation of plant remains: Bulgaria. In E.S. Higgs (ed.) *Papers in Economic Prehistory*, pp. 149-159. Cambridge: Cambridge University Press.

Dennell, R.W. 1974 Prehistoric crop processing activities. *Journal of Archaeological Science* 1: 275-284.

Dennell, R.W. 1976 The economic importance of plant resources represented on archaeological sites. *Journal of Archaeological Science* 3: 229-247.

Doherty, C. 2007 Clay sourcing, Çatalhöyük 2007 - Matching the materials and the landscape. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2007 Archive Report*. Online at http://www.catalhoyuk.com.

Doherty, C., M. Charles and A. Bogaard 2007 Preliminary sediment coring to clarify "clay" sources and potential land-use around Çatalhöyük. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2007 Archive Report*. Online at http://www.catalhoyuk.com

Doherty, C, M. Charles and A. Bogaard 2008 Landscape Coring. I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2007 Archive Report*. Online at http://www.catalhoyuk.com

Doherty, C. and E. Camizuli 2008 Clay-Based Materials Report. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2008 Archive Report*. Online at http://www.catalhoyuk.com

Doherty, C. in press/2013 Sourcing Çatalhöyük's clays. In I. Hodder (ed.) *Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Donovan, P. 2005 A Note on Modelling Field Location. In I. Hodder (ed.) *Çatalhöyük Perspectives: Themes from the 1995-9 Seasons*, Çatalhöyük Project Vol. 6, pp. 51-53. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Driessen, P.M. and T.D. de Meester 1969 *Soils of the Çumra Area, Turkey*. Agricultural Research Reports 270. Wageningen: Centre for Agricultural Publishing and Documentation.

Driessen, P.M. 1970 *Salinity and alkalinity in the Great Konya Basin, Turkey*. Wageningen: Centre for Agricultural Publishing and Documentation.

Dönmez, E.O. 2005 Early Bronze Age Crop Plants from Yenibademli Höyük (Gökçeada), Western Turkey. *Environmental Archaeology* 10: 39-49.

Düring, B.S. 2001 Social dimensions in the architecture of Neolithic Çatalhöyük. *Anatolian Studies* 51: 1-18.

Düring, B.S. 2005 Building continuity in the Central Anatolian Neolithic. Exploring the meaning of buildings at Aşıklı and Çatalhöyük. *Journal for Mediterranean Archaeology* 18: 1-20.

Düring, B.S. and A. Marciniak 2005 Households and communities in the central Anatolian Neolithic. *Archaeological Dialogues* 12: 165-187.

Düring, B.S. 2006 *Constructing Communities.Clustered Neighbourhood Settlements of the Central Anatolian Neolithic ca. 8500-5500 Cal. BC*. Leiden: Nederlands Instituut voor Het Nabije Oosten.

Düring, B.S., 2007 The articulating of houses at Neolithic Çatalhöyük, Turkey. Beck, R.A.Jr. (ed.) *The durable house: house society models in archaeology*, pp. 130-153. Carbondale: Center for Archaeological Investigations, Southern Illinois University Carbondale.

Duru, G. and M. Özbaşaran 2005 A non-domestic site in Central Anatolia. *Anatolia Antiqua* 8: 15-28.

Eastwood, W., M.J. Leng, N. Roberts and B. Davis 2007 Holocene climate change in the eastern Mediterranean region: a comparison of stable isotope and pollen data from a lake record in southwest Turkey. *Journal of Quaternary Science* 22 (4): 327-341.

Ehleringer, J.R. and R.K. Monson 1993 Evolutionary and ecological aspects of photosynthetic pathway variation. *Annual Review of Ecology and Systematics* 24: 411-439.

Elger, A. and M.H. Barrat-Segretain 2004 Plant palatability can be inferred from a single-date feeding trial. *Functional Ecology* 18: 483-488.

Ellenberg, H. 1950 *Landwirtschaftliche Pflanzensoziologie I: Unkrautgemeinschaften als Zeiger für Klima und Boden*. Stuttgart: Eugen Ulmer**.**

Ellenberg, H. 1988 (4th edition, English translation by Gordon K. Strutt) *Vegetation ecology of Central Europe*. Cambridge: Cambridge University Press.

Erkal, A. 1999 Experimental Work at Çatalhöyük. In I. Hodder and the Çatalhöyük Research Trust (eds.). *Çatalhöyük 1999 Archive Report*. Online at http://www.catalhoyuk.com.

Erkal, A. 2006 *The ethnobotany of wild food plant use in the Konya Basin: a quantitative and ethnoarchaeological approach*. Unpublished MSc thesis submitted to Graduate School of Natural and Applied Sciences of Middle East Technical University.

Erol, O. 1991 Turkey and Cyprus. In E.D. Bird and M. Schwarts (eds.) *The World Coastline*, pp. 491–500. New York: Van Nostrand Reinfold Company.

Ertuğ-Yaraş, F. 1997 *An Ethnoarchaeological Study of Subsistance and Plant Gathering in central Anatolia*. Unpublished Ph.D thesis. Washington University, Dept. of Anthropology. St. Louis, Missouri.

Ertuğ, F. 2000 An ethnobotanical study in Central Anatolia (Turkey). *Economic Botany* 54: 155- 182.

Ertuğ, F. 2004a Recipes of old tastes with einkorn and emmer wheat. *TÜBA-AR* 7: 177-188.

Ertuğ, F. 2004b Wild edible plants of the Bodrum area (Muğla, Turkey). *Turkish Journal of Botany* 28: 161-174.

Ertuğ, F. 2006 An overview of the plaited crafts of turkey (Anatolia and Thrace). In F. Ertuğ (ed.) *Proceedings of the IVth International Congress of Ethnobotany (ICEB 2005)*, pp. 297-306. Turkey: Yayinlari.

Esin, U., E. Biçakçi, M. Özbaşaran, N. Balkan-Atlı, D. Berker, I. Yagmur, I. and A.K. Atli 1991 Salvage excavations at the Pre-Pottery Site of Aşıklı Höyük in Central Anatolia. *Anatolica* 17: 123-174.

Esin, U. and S. Harmankaya 1999 Aşıklı in the frame of Central Anatolian Neolithic. In M. Özdoğan and N. Başgelen (eds.) *Neolithic in Turkey, the cradle of civilization. New discoveries*, pp. 115–132. Istanbul: Arkeoloji ve Sanat Yayinlari.

Evershed, R.P., S. Payne, A.G. Sherratt, M.S. Copley, J. Coolidge, D. Urem-Kotsu, K. Kotsakis, M. Özdoğan, A.E. Özdoğan, O. Nieuwenhuyse, P.M.M.G. Akkermans, D. Bailey, R-R. Andeescu, S. Campbell, S. Farid, I. Hodder, N. Yalman, M. Özbaşaran, E. Bıçakcı, Y. Garfinkel, T. Levy and M.M. Burton 2008 Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature* 445: 528-531.

Ewert, A. and G.A.Wiebe 1961 Classification of barley varieties grown in the United States and Canada in 1958. United States Department of Agriculture. *Technical Bulletin 1224.*

Fahmy, A.G., S. Khodary, M. Fadl and I. El-Garf 2008 Plant Macroremains from an Elite Cemetery at Predynastic Hierakonpolis, Upper Egypt. *International Journal of Botany* 4: 205-212.

Fairbairn, A., E. Asouti, J. Near and D. Martinoli 2002 Macro-botanical evidence for plant use at Neolithic Çatalhöyük south-central Anatolia, Turkey. *Vegetation History and Archaeobotany* 11: 41-54.

Fairbairn, A., J. Near and D. Martinoli 2005 a Macrobotanical Investigation of the North, South and KOPAL Area Excavations at Çatalhöyük East. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons,* Çatalhöyük Project Vol. 4, pp. 137-201. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Fairbairn, A, E. Asouti, N. Russell and J. Swogger 2005b Seasonality. In I. Hodder (ed.) *Çatalhöyük perspectives: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 6, pp. 93-108. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Fairbairn, A. 2005 A history of agricultural production at Neolithic Çatalhöyük East, Turkey. *World Archaeology* 37 (2): 197–210.

Fairbairn A.S., D. Martinoli, A. Butler and G. Hillman 2007 Wild plant seed storage at Neolithic Çatalhöyük East, Turkey. *Vegetation History and Archaeobotany* 16: 467-479.

Farid, S. and C. Cessford 1999 Archive Summary for the South Area. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1999 Archive Report*. Online at http:// www.catalhoyuk.com.

Farid, S. 2000 The Excavation Process at Çatalhöyük. In I. Hodder (ed.) *Towards Reflexive Method in Archaeology: The Example at Çatalhöyük*, pp. 19-35. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Farid, S. 2007 Neolithic Excavations in the South Area, East Mound, Çatalhöyük 1995-99. In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, pp. 41-342. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Farid, S. 2008 A review of the Mellaart Level system and the introduction of a new phasing system at Çatalhöyük 2008. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2008 Archive Report*. Online at http://www.catalhoyuk.com

Flannery, K.V. 1972 The Origins of the Village as a Settlement Type in Mesoamerica and the Near East: A Comparative Study. P. J. Ucko, R. Tringham, and G. W. Dimbleby (eds.) *Man, Settlement and Urbanism*, pp. 23-53. London: Duckworth.

Flannery, K.V. 1995 Prehistoric Social Evolution. In C. Ember and M. Ember (eds.) *Research Frontiers in Anthropology*, pp. 1–26. New Jersey: Prentice-Hall, Englewood Cliffs.

Flannery, K.V. 2002 The origins of the village revisited: from nuclear to extended households. *American Antiquity* 67: 417-433.

Fenton, A. 1985 *The Shape of the Past 1: Essays in Scottish Ethnology*. Edinburgh: John Donald Publishers.

Filipovic, D. 2012 Observation of "traditional" agriculture in Kastamonu, Turkey in relation to the evidence of crop husbandry at Neolithic Çatalhöyük, Central Anatolia. *Issues in Ethnology and Anthropology* 4 (7): 1167-1191.

Fontugne M., C. Kuzucuoğlu, M. Karabıyıkoğlu, C. Hatte and J-F. Pastre 1999 From Pleniglacial to Holocene: a 14C chronostratigraphy of environmental change in the Konya Basin, Turkey. *Quaternary Science Reviews* 18: 573-591.

French, D.H., G.C. Hillman, S. Payne and R.J. Payne 1972 Excavations at Can Hasan III 1969-1970. In E.S. Higgs (ed.) *Papers in Economic Prehistory*, pp. 181-190. Cambridge: Cambridge University Press.

Fuller, D.Q and S.A. Weber 2005 Formation Processes and Paleoethnobotanical Interpretation in South Asia. *Journal of Interdisciplinary Studies in History and Archaeology* 2 (1): 93-115.

Fuller, D.Q., C.J. Stevens and M. McClatchie 2005 Routine Activities, Tertiary Refuse and Labor Organization: Social Inference from Everyday Archaeobotany. In M. Madella and M. Savard (eds.) *Ancient Plants and People. Contemporary Trends in Archaeobotany*. Tucson: University of Arizona Press.

Fuller, D.Q. 2007 Contrasting patterns in crop domestication and domestication rates: recent archaeobotanical insights from the Old World. *Annals of Botany* 100: 903-924.

Fuller, D.Q. and R.G. Allaby 2009 Seed dispersal and crop domestication: shattering, germination and seasonality in evolution under cultivation. In L. Ostergaard (ed.) *Annual Plant Reviews*, Vol. 38, *Fruit Development and Seed Dispersal*, pp. 238-295. Oxford: Wiley-Blackwell.

Fuller, D.Q. and C.J. Stevens 2009 Agriculture and the Development of Complex Societies: An Archaeobotanical Agenda. In A. Fairbairn and E. Weiss (eds.) *From foragers to farmers: Papers in honour of Gordon Hillman*, pp. 37-57. Oxford: Oxbow.

Fuller, D.Q., G. Willcox and R.G. Allaby 2011 Early agricultural pathways: moving outside the 'core area' hypothesis in Southwest Asia. *Journal of Experimental Botany* 63: 617-633.

Gardener, C.J., J.G. McIvor and A. Jansen 1993 Passage of legume and grass seeds through the digestive tract of cattle and their survival in faeces. *Journal of Applied Ecology* 30: 63–74.

Garner, F.H. 1963 The palatability of herbage plants. *Grass and Forage Science* 18: 79-89.

Gérard, F. 2002 CANeW archaeological sites databases. Central Anatolia, 9th-6th millennia cal. BC. Appendix in F. Gérard and L. Thissen (eds.) 2002 *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001, pp. 339-348. Istanbul: Ege Yayınları.

Gérard, F. and L. Thissen (eds.) 2002 *The Neolithic of Central Anatolia: Internal developments and external relations during the 9th-6th millennia cal BC*, Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001. Istanbul: Ege Yayınları.

Giuliani, A., A. Karagöz and N. Zencirci 2009. Emmer (*Triticum dicoccon*) Production and Market Potential in Marginal Mountainous Areas of Turkey. *Mountain Research and Development* (MRD) 29 (3): 220-229. Online at http://www.mrd-journal.org.

Green, F.J. 1979 Phosphatic mineralization of seeds from archaeological sites. *Journal of Archaeological Science* 6: 279-284.

Green, F.J 1982 Problems of interpreting differentially preserved plant remains from excavations of

medieval urban sites. In A.R. Hall and H.K. Kenward (eds.) *Environmental Archaeology in the Urban Context*, pp. 40-46. London: Council for British Archaeology Research Report 23.

Gregg, S.A. 1988 *Foragers and farmers: Population interaction and agricultural expansion in prehistoric Europe*. Chicago (IL): University of Chicago Press.

Grigg, D. 1974 *The Agricultural Systems of the World: an Evolutionary Approach*. Cambridge: Cambridge University Press.

Grime, J.P. 1979 *Plant Strategies and Vegetation Processes*. Chichester: John Wiley and Sons.

Grime, J.P., Hodgson, J.G. and R. Hunt 1988 *Comparative Plant Ecology: a Functional Approach to Common British species*. London: Unwin Hyman.

Grime, J.P., J.G. Hodgson and R. Hunt 1990 *The Abridged Comparative Plant Ecology*. London: Unwin Hyman.

Grime, J.P. 2002 *Plant Strategies, Vegetation Processes, and Ecosystem Properties*. Chichester: John Wiley and Sons.

Grupe, G. 2007 Taphonomic and Diagenetic Processes. In W. Henke, I. Tattersall and T. Hardt (eds.) *Handbook of Palaeoanthropology*, Vol. 1, pp. 241-260. Berlin – Heidelberg: Springer.

Guest, E. and A. Al-Rawi 1966 *Flora of Iraq*, Vol. 1. Baghdad: Ministry of Agriculture of the Republic of Iraq.

Güner, A., N. Özhatay, T. Ekim and K.H.C. Başer 2001 *Flora of Turkey and the East Aegean Islands* (Second supplement), Vol. 11. Edinburgh: Edinburgh University Press.

Hajnalová, M. and D. Dreslerová 2010 Ethnobotany of einkorn and emmer in Romania and Slovakia: towards interpretation of archaeological evidence. *Památky Archeologické* CI: 169-202.

Hald, M.M. 2008 *A thousand years of farming: late Chalcolithic agricultural practices at Tell Brak in northern Mesopotamia*. Oxford: BAR International Series.

Halstead, P. 1987 Traditional and Ancient Rural Economy in Mediterranean Europe: plus ça change? *Journal of Hellenic Studies* 107: 77-87.

Halstead, P. 1989 Like rising damp? An ecological approach to the spread of farming in south east and central Europe. In A. Milles, D. Williams and N. Gardner (eds.) *The Beginnings of Agriculture*, pp. 23-53. Oxford: BAR International Series 496.

Halstead, P. and J. O'Shea (eds.) 1989 *Bad Year Economics: cultural responses to risk and uncertainty*. Cambridge: Cambridge University Press.

Halstead, P. 1995 Plough and power: the economic and social significance of cultivation with the ox-drawn ard in the Mediterranean. *Bulletin on Sumerian Agriculture* 8: 11-22.

Halstead, P. 1996 Pastoralism or household-herding? Problems of scale and specialization in early Greek animal husbandry. *World Archaeology* 28: 20-42.

Halstead, P. 2000 Land use in postglacial Greece: cultural causes and environmental effects. In P. Halstead and C. Frederick (eds.) *Landscape and Land Use in Postglacial Greece*, pp. 110-128. Sheffield: Sheffield Academic Press.

Halstead P. 2006 Sheep in the garden: the integration of crop and livestock husbandry in early farming regimes of Greece and Southern Europe. In D. Serjeantson and D. Field (eds.) *Animals in the Neolithic of Britain and Europe*, pp. 42-55. Oxford: Oxbow.

Halstead, P. 2012 Feast, Food and Fodder in Neolithic-Bronze Age Greece: Commensality and the Construction of Value. In S. Pollock (ed.) *Between Feasts and Daily Meals: Toward an Archaeology of Commensal Spaces*, pp. 21-51. Journal for Ancient Studies, special volume 2. Berlin: Excellence Cluster Topoi.

Hamzaoğlu, E. and A. Aksoy 2009 Phytosociological Studies on the Halophytic Communities of Central Anatolia. *Ekoloji* 71: 1-14**.**

Harris, D.R. 2002 Development of the agro-pastoral economy in the Fertile Crescent during the Pre-Pottery Neolithic period. In R.T.J. Cappers and S. Bottema (eds.) *The Dawn of Farming in the Near East*, pp. 67-84. Berlin: Ex oriente.

Hastorf, C.A. 1996 Botanical Archive Report 1996 In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1996 Archive Report.* Online at http://www.catalhoyuk.com.

Hastorf, C.A. and J. Near 1997 Archaeobotanical archive report. In I. Hodder and the Çatalhöyük Research Trust (eds.). *Çatalhöyük 1997 Archive Report*. Online at http://www.catalhoyuk.com.

Hastorf, C.A. and M.F. Wright 1998 Interpreting wild seeds from archaeological sites: a dung charring experiment from the Andes. *Joumal of Ethnobiology* 18 (2): 211-227.

Hastorf, C.A. 2005 Macrobotanical investigation: field methods and laboratory analysis procedures. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*, Çatalhöyük Project Vol. 4, pp. 129-135. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hauptmann, H. 1993 Nevalı Çori: Eine Siedlung des akeramischen Neolithikums am mittleren Euphrat (1991/92). *Nürnberger Blätter* 8/9: 15-33.

Hayden, B. 2001 Fabulous feasts: a prolegomenon to the importance of feasting. In M. Dietler and B. Hayden (eds.) *Feasts: Archaeological and Ethnographic Perspectives on Food, Politics, and Power*, pp. 23-64. Washington D.C.: Smithsonian Institution Press.

Helbaek, H. 1964 First impressions of the Çatal Hüyük plant husbandry. *Anatolian Studies* 14: 121-123.

Helbaek, H. 1970 The Plant Husbandry of Hacilar. In J. Mellaart *Excavations at Hacilar*, pp. 189-244. Edinburgh: Edinburgh University Press.

Henton, E.M. 2010 *Herd management and the social role of herding at Neolithic Çatalhöyük: an investigation using oxygen isotope and dental microwear evidence in sheep*. Unpublished Ph.D. thesis, University College London, Institute of Archaeology.

Henton, E. 2012 The combined use of oxygen isotopes and microwear in sheep teeth to elucidate seasonal management of domestic herds: the case study of Çatalhöyük, central Anatolia. *Journal of Archaeological Science* 39: 3264-3276.

Henton, E. in press/2013 Oxygen stable isotope and dental microwear evidence of herding practices at Çatalhöyük. In I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Higgs, E.S. and C. Vita-Finzi 1972 Prehistoric economies: A territorial approach. In E.S. Higgs (ed.) *Papers in Economic Prehistory*, pp. 27-36. Cambridge: Cambridge University Press.

Hillman, G.C. 1973 Crop husbandry and food production: modern models for the interpretation of plant remains. *Anatolian Studies* 23: 241-244.

Hillman, G.C. 1981 Reconstructing crop husbandry practices from the charred remains of crops. In R. Mercer (ed.) *Farming Practice in British prehistory*, pp. 123-162. Edinburgh: Edinburgh University Press.

Hillman, G.C. 1984a Interpretation of archaeological plant remains: Application of ethnographic models from Turkey. In W.A. Casparie and W. van Zeist (eds.) *Plants and Ancient Man*: *Studies in palaeoethnobotany*, pp. 1-41. Rotterdam: Balkema.

Hillman G.C. 1984b Traditional Husbandry and Processing of Archaic Cereals in Recent Times: the operations, products and equipment which might feature in Sumerian Texts. Part I: the glume-wheats. *Bulletin on Sumerian Agriculture* 1: 114–152.

Hillman, G.C. 1985 Traditional husbandry and processing of archaic cereals in modern times. Part II, the free-threshing cereals. *Bulletin on Sumerian Agriculture* 2: 1-31.

Hillman, G.C., E. Madeyska and J.G. Hather 1989a Wild plant foods and diet of Late Palaeolithic Wadi Kubbaniya: the evidence from charred remains. In F. Wendorf, R. Schild and A. Close (eds.) *The Prehistory of Wadi Kubbaniya Vol. 2: stratigraphy, palaeoeconomy and environment*, pp. 162-242. Dallas: Southern Methodist University Press.

Hillman, G.C., S. Colledge and D.R. Harris 1989b Plant food economy during the Epi-Palaeolithic period at Tell Abu Hureyra Syria: Dietary diversity, seasonality and modes of exploitation. In D.R. Harris and G.C. Hillman (eds.) *Foraging and farming: Evolution of plant exploitation*, pp. 240–268. London: Unwin and Hyman.

Hillman, G.C. 1991 Phytosociology and Ancient Weed Floras: Taking Account of Taphonomy and Changes in Cultivation Methods. In D.R. Harris and Thomas, K.D. (eds.), *Modelling Ecological Change*, pp. 27-40. London: Institute of Archaeology, University College London.

Hillman, G.C. and M.S. Davies 1992 Domestication rate in wild wheats and barley under primitive cultivation: preliminary results and archaeological implications of field measurements of selection coefficient. In P.C. Anderson (ed.) *Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques*, pp. 113-158. Paris: Centre de Recherches.

Hillman, G.C. 2000a The potential vegetation under modern climatic conditions. In A.M.T. Moore, G.C. Hillman and A.J. Legge (eds.) *Village on the Euphrates: from foraging to farming at Abu Hureyra*, pp. 49-52. New York: Oxford University Press.

Hillman, G.C. 2000b The plant food economy of Abu Hureyra 1 and 2. In A.M.T. Moore, G.C. Hillman and A.J. Legge (eds.) *Village on the Euphrates: from foraging to farming at Abu Hureyra*, pp. 327-398. New York: Oxford University Press.

Hingh, A.E de 2000 *Food production and food procurement in the Bronze Age and Early Iron Age (2000-500 BC). The organisation of a diversified and intensified agrarian system in the Meuse-Demer-Scheldt region (The Netherlands and Belgium) and the region of the river Moselle (Luxemburg and France)*. Leiden: Faculty of Archaeology, Leiden University.

Hodder, I. 1994 Introduction. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1994 Archive Report*. Online at http://www.catalhoyuk.com.

Hodder, I. (ed.) 1996 *On the Surface: Çatalhöyük 1993*-95. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Hodder, I. 1999 Renewed Work at Çatalhöyük. in Özdogan, M., and Basgelen, N., (ed's). 1999. Neolithic in Turkey: the Cradle of Civilization. Istanbul: Arkeoloji ve Sanat Yayinlari. Vol 1 157-64 and Vol 2 129-35.

Hodder, I. (ed.) 2000 *Towards Reflexive Method in Archaeology: The Example at Çatalhöyük.* Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Hodder, I. 2003 The Lady and the Seed: some thoughts on the role of agriculture in the 'Neolithic Revolution'. In M. Özdoğan, H. Hauptmann and N. Başgelen (eds.) *Köyden Kente. Yakındoğu'da Ilk Yerleşimler. From Villages to Cities. Early Villages in the Near East* (vol.1-2). Studies Presented to Ufuk Esin, pp. 129-137. Istanbul: Arkeoloji ve Sanat Yayinlari.

Hodder, I. and C. Cessford 2004 Daily practice and social memory at Çatalhöyük, *American Antiquity* 69 (1): 17-40.

Hodder, I. 2005 Introduction. I. Hodder (ed.) *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 5. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hodder, I. (ed.) 2005a *Inhabiting Çatalhöyük: reports from the 1995-99 seasons.* Çatalhöyük Project Vol. 4. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hodder, I. (ed.) 2005b *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*.

Çatalhöyük Project Vol. 5. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hodder, I. (ed.) 2005c *Çatalhöyük perspectives: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 6. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hodder, I. 2006 *Çatalhöyük: the Leopard's Tale. Revealing the mysteries of Turkey's ancient 'town'*. London: Thames and Hudson.

Hodder, I. (ed.) 2007 *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hodder, I., C. Cessford and S. Farid 2007 Introduction to Methods and Approach. In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, pp. 3-24. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Hodder, I. 2007 Çatalhöyük in the Context of the Middle Eastern Neolithic. *Annual Review of Anthropology* 36: 105-120.

Hodder, I. 2009 Upper stories at Çatalhöyük. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2009 Archive Report*. Online at http://www.catalhoyuk.com.

Hodgson, J.G. 1991 The use of ecological theory and autoecological datasets in studies of endangered plant and animal species and communities. *Pirineos* 138: 3-28.

Holzner, W. 1978 Weed Species and Weed Communities. *Vegetatio* 38: 13-20.

Holzner, W. and Numata, M. (eds.) 1982. *Biology and Ecology of Weeds*. The Hague: Junk.

Hoppé, C. 1999 *A Thousand Years of Farming: Agricultural Practices from the Byzantine to Early Ottoman Period at Khirbet Faris, the Kerak Plateau, Jordan*. Unpublished PhD dissertation. Department of Archaeology, University of Sheffield.

Hroudová, Z., P. Zákravský, M. Ducháček and K. Marhold 2007 Taxonomy, distribution and ecology of *Bolboschoenus* in Europe. *Ann. Bot. Fennici* 44: 81-102.

Hubbard, C.E. 1984 (3rd edition) *Grasses. A guide to their structure, identification, uses, and distribution in the British Isles*. London: Penguin Books.

Hussain, F. and M.J. Durrani 2009 Seasonal availability, palatability and animal preferences of forage plants in Harboi arid range land, Kalat, Pakistan. *Pak. J. Bot.* 41 (2): 539-554.

Hüppe, J. and H. Hofmeister 1990 Syntaxonomische Fassung und Übersicht über die Ackerunkrautgesellschaften der Bundesrepublik Deutschland. *Berichte der Reinhardt Tüxen-Gesellschaft* 2: 61-81.

Hütteroth, D. 1968 *Ländliche Siedlungen im südlichen Inneranatolien in den letzten vierhundert Jahren*. Göttinger Geographische Abhandlungen 46.

Ibáñez Estévez, J.J., J.E. Gonzalez Urquijo, L. Peña-Chocarro, L. Zapata and V. Beugnier 2001 Harvesting without sickles. Neolithic examples from humid mountain areas. In S. Beyries and P. Pétrequin (eds.) *Ethno-archaeology and its transfers*, pp. 22-36. BAR International Series 983. Oxford: Archaeopress.

Ingold, T. 1996 Growing Plants and raising animals: an anthropological perspective on domestication. In D.R. Harris (ed.) *The Origins and Spread of Agriculture and Pastoralism in Eurasia*, pp. 12-24. London: UCL Press.

Jacomet, S. and Kreuz, A. 1999 *Archäobotanik*. Stuttgart: Eugen Ulmer

Jacomet, S. 2006 *Identification of cereal remains from archaeological sites*. Archaeobotany Lab IPAS, Basel University.

Jacomet, S. 2007 Use in Environmental Archaeology. Section in H. Birks Plant Macrofossil Methods and Studies. In S. Elias (ed.) *Encyclopedia of Quaternary Science*, Vol. 3, pp. 2384-2412. Oxford: Elsevier.

Jenkins, E. 2005 The Çatalhöyük Microfauna: Preliminary Results and Interpretations. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons.* Çatalhöyük Project Vol. 4, pp. 111-116. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Jones, G. 1981 Crop processing at Assiros Toumba - a Taphonomic Study. *Zeitschrift für Archäologie* 15: 105-111.

Jones, G.E.M. 1983 *The use of ethnographic and ecological models in the interpretation of archaeological plant remains: case studies from Greece*. Unpublished Ph.D. dissertation. Cited in Valamoti, M-S. 2004 *Plants and People in Late Neolithic and Early Bronze Age Northern Greece. An archaeobotanical investigation*. Oxford: BAR International Series.

Jones, G. 1984 Interpretation of archaeological plant remains: ethnographic models from Greece. In W.A. Casparie and W. van Zeist (eds.): *Plants and Ancient Man*: *Studies in palaeoethnobotany*, pp. 43-61. Rotterdam: Balkema.

Jones, G. 1987 A statistical approach to the archaeological identification of crop processing. *Journal of Archaeological Science* 14: 311-323.

Jones, G. 1990 The application of present-day cereal processing studies to charred archaeobotanical remains. *Circaea* 6 (2): 91-96.

Jones, G. 1991 Numerical analysis in archaeobotany. In W. van Zeist, K. Wasylikowa and K.E. Behre (eds.) *Progress in Old World palaeoethnobotany*, pp. 63-80. Rotterdam: Balkema.

Jones, G. 1992 Weed phytosociology and crop husbandry: identifying a contrast between ancient and modern practice. *Review of Palaeobotany and Palynology* 73: 133–143.

Jones, G. and P. Halstead 1995 Maslins, mixtures and monocrops: on the interpretation of archaeological crop samples of heterogeneous composition. *Journal of Archaeological Scienc*e 22: 103-114

Jones, G., A. Bogaard, P. Halstead, M. Charles and H. Smith 1999 Identifying the intensity of crop husbandry on the basis of weed floras. *Annual of the British School at Athens* 94: 167-189.

Jones, G., A. Bogaard, M. Charles and J.G. Hodgson 2000a Distinguishing the effects of agricultural practices relating to fertility and disturbance: a functional ecological approach in archaeobotany. *Journal of Archaeological Science* 27: 1073-1084.

Jones, G., S. Valamoti and M. Charles 2000b Early crop diversity: a "new" glume wheat from northern Greece. *Vegetation History and Archaeobotany* 9: 133-146.

Jones, G. 2002 Weed ecology as a method for the archaeobotanical recognition of crop husbandry practices. *Acta Palaeobotanica* 42: 185-193.

Jones, G. 2005 Garden cultivation of staple crops and its implications for settlement location and continuity. *World Archaeology* 37 (2): 164-176.

Jones, G., M. Charles, A. Bogaard and J. Hodgson 2010 Crops and weeds: the role of weed functional ecology in the identification of crop husbandry methods. *Journal of Archaeological Science* 37: 70-77.

Jones, H., F.J. Leigh, I. Mackay, M.A. Bower, L.M.J. Smith, M.P. Charles, G. Jones, M.K. Jones, T.A. Brown and W. Powell 2008 Population-Based Resequencing Reveals That the Flowering Time Adaptation of Cultivated Barley Originated East of the Fertile Crescent. *Molecular Biology and Evolution* 25 (10): 2211–2219.

Jones, M. 1988 The phytosociology of early arable weed communities with special reference to southern England. In H. Küster (ed.) *Der prähistorische Mensch und seine Umwelt.* Festschrift

Udelgard Körber-Grohne, pp. 43-51. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg, Band 31.

Jones, M.D., C.N. Roberts and M.J. Leng 2007 Quantifying climatic change through the last glacial–interglacial transition based on lake isotope palaeohydrology from central Turkey. *Quaternary Research* 67: 463–473.

Karg, S. 1998 Winter- and Spring-Foddering of Sheep-Goat in the Bronze Age Site of Flavè-Carera, Northern Italy. *Environmental Archaeology* 1: 87-94.

Kemp, D.D 1998 *The Environment Dictionary*. London: Routledge.

Kenyon, K.M. 1985 (4th edition) *Archaeology in the Holy Land*. London: Methuen & Co. Ltd.

Kislev, M.E. and S. Rosenzweig 1991 Influence of experimental charring on seed dimensions of pulses. In E. Hajnalova (ed.) *Palaeoethnobotany and archaeology*, pp. 143-157. International work-group for Palaeoethnobotany 8th symposium Nitra-Nové Vozokany 1989. Nitra: Acta Interdiscip. Archaeol. 7.

Knörzer, K-H. 1971 Urgeschichtliche Unkrauter im Rheinland. Ein Beitrag zur Entstehung der Segetalgesellschaften, *Vegetatio* 23: 89-111.

Kohler-Schneider, M. 2003 Contents of a storage pit from late Bronze Age Stillfried, Austria: another record of the "new" glume wheat. *Vegetation History and Archaeobotany* 12: 105-111.

Kreuz, A. and N. Boenke 2002 The presence of two-grained einkorn at the time of the Bandkeramik culture. *Vegetation History and Archaeobotany* 11: 233-240.

Kuijt, I. 2000 Keeping the Peace: Ritual, Skull Caching and Community Integration in the Levantine Neolithic. In I. Kuijt (ed.) *Life in Neolithic farming communities; social organisation, identity and differentiation*, pp. 137-164. New York: Kluwer Academic.

Kuijt, I. (ed.) 2000 *Life in Neolithic farming communities; social organisation, identity and differentiation.* New York: Kluwer Academic.

Kuijt, I. and N. Goring-Morris 2002 Foraging, farming, and social complexity in the Pre-Pottery Neolithic of the Southern Levant: a review and synthesis. *Journal of World Prehistory* 16: 361-440.

Kühn, M. and P. Hadorn 2004 Pflanzliche Makro- und Mikroreste aus Dung von Wiederkäuern. In S. Jacomet, U. Leuzinger and J. Schibler (eds.) Die jungsteinzeitliche Seeufersiedlung Arbon – Bleiche 3. Umwelt und Wirtschaft. *Archäologie im Thurgau* 12: 327-350.

Kültür, Ş. 2008 An ethnobotanical study of Kırklareli (Turkey). *Phytologia Balcanica* 14 (2): 279 – 289.

Küster, H. 1984 Neolithic plant remains from Eberdingen-Hochdorf, southern Germany. In W.A. Casparie and W. van Zeist (eds.) *Plants and Ancient Man*: *Studies in palaeoethnobotany*, pp. 307-311. Rotterdam: Balkema.

Küster, H. 1991 Phytosociology and Archaeobotany. In D. R. Harris and K. D. Thomas (eds.) *Modelling Ecological Change*, pp. 17-26. London: Institute of Archaeology, University College London.

Kuzucuoğlu, C., R. Parish and M. Karabiyikoglu 1998 The dune systems of the Konya Plain (Turkey): their relation to the environmental changes in central Anatolia during the Late Pleistocene and Holocene. *Geomorphology* 23: 257–271.

Kuzucuoğlu, C. 2002 Environmental setting and evolution from the 9th to the 5th millennium cal BC in Central Anatolia: an introduction to the study of relations between environmental conditions and the development of human societies. In L. Thissen and F. Gérard (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, pp. 33-58. Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001. Istanbul: Ege Yayınları.

Leatherman, T.L., R.B. Thomas and S. Luerssen 1989 Challenges to Seasonal Strategies of Rural Producers: Uncertainty and Conflict in the Adaptive Process. In R. Huss-Ashmore, J.J. Curry and R.K Hitchcock (eds.) *Coping with Seasonal Constraints*, pp. 5-8. MASCA Research papers in Science and Archaeology 5. Philadelphia: The University Museum, University of Pennsylvania.

Lange, A.G. 1990 *Plant Remains from a Native Settlement at the Roman Frontier: De Horden near Wijk bij Duurstede: a Numerical Approach*. Amersfoort: ROB**.**

Last, J. 2005a Pottery from the East Mound. In I. Hodder (ed) *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*. Catalhöyük Project Vol. 5, pp. 101-138. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Last, J. 2005b Art. In I. Hodder (ed) *Çatalhöyük perspectives: reports from the 1995-99 seasons*, Catalhöyük Project Vol. 6, pp. 197-208. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Lavorel, S., S. Díaz, J.H.C Cornelissen, E. Garnier, S.P. Harrison, S. McIntyre, J.G. Pausas, N. Pérez-Harguindeguy, C. Roumet and C. Urcelay 2007 *Plant Functional Types: Are We Getting Any Closer to the Holy Grail?* In J.G. Canadell, L.F. Pitelka and D. Pataki (eds.) *Terrestrial Ecosystems in a Changing World*, pp. 149-160. Berlin, Heidelberg: Springer-Verlag**.**

Lemke, G. and M. Sturm 1997 δ18O and Trace Element Measurements as Proxy for the Reconstruction of Climate Changes at Lake Van (Turkey): Preliminary Results. In N.D. Dalfes (ed.) *Third Millennium BC Climate Change and Old World Collapse*. NATO ASI Series 149: 653-678.

Limbrey, S. 2010 Yard Deposits and Building Materials at Jeitun. In D.R. Harris (ed.) *Origins of Agriculture in western Central Asia: archaeological and environmental investigations in southern Turkmenistan.*, pp. 125-130. Philadelphia: University of Pennsylvania Press.

Linseele, V., E. Marinova, W. van Neer and P. Vermeersch 2010 Sites with Holocene Dung Deposits in the Eastern Desert of Egypt: Visited by Herders? *Journal of Arid Environments* 74 (7): 818-828.

Lisonbee, L.D., J.J. Villalba and F.D. Provenza 2009 Effects of tannin on selection by sheep of forages containing alkaloids, tannins and saponins. *Journal of the Science of Food and Agriculture* 89 (15): 2668-2677.

Lososová, Z., M. Chytrý, S. Cimalová, Z. Kropáč, Z. Otýpková, P. Pyšek and L. Tichý 2004 Weed vegetation of arable land in Central Europe: Gradients of diversity and species composition. *Journal of Vegetation Science* 15: 415-422.

Lösch, S., G. Grupe and J. Peters 2006 Stable Isotopes and Dietary Adaptations in Humans and Animals at Pre-Pottery Neolithic Nevalı Çori, Southeast Anatolia. *American Journal of Physical Anthropology* 131: 181–193.

Love, S. 2012 The Geoarchaeology of Mudbricks in Architecture: A Methodological Study from Çatalhöyük, Turkey. *Geoarchaeology: An International Journal* 27: 140-156.

Lyle-Kalças, E. 1992 *Food from the Fields, Edible Wild Plants of Aegean Turkey*. Izmir: Bilgehan Press.

Maher, L.A., T. Richter and J.T Stock 2012 The Pre-Natufian Epipaleolithic: Long-Term Behavioral Trends in the Levant. *Evolutionary Anthropology* 21: 69–81.

Marciniak, A. 2008 Communities, households and animals. Convergent developments in Central Anatolia and Central European Neolithic. *Documenta Praehistorica* 35: 93-109.

Märkle, T. and M. Rösch 2008 Experiments on the effects of carbonization on some cultivated plant seeds. *Vegetation History and Archaeobotany* 17: 257-263.

Martin, L. and N. Russell 2000 Trashing Rubbish. In I. Hodder (ed.) *Towards Reflexive Method in Archaeology: The Example of Çatalhöyük*, pp. 57-70. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Martin, L., N. Russell and D. Carruthers 2002 Animal remains from the central Anatolian Neolithic. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, pp. 193-206. Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001. Istanbul: Ege Yayınları.

Martínková, J., L. Klimeš and J. Klimeš 2011 Multiple Regenerative Strategies of Short-Lived Species: An Effect on Geographical Distribution, Preference of Human-Made Habitats and Invasive Status. *Folia Geobot* 46: 181–189.

Mason, S. and M. Nesbitt 2009 Acorns as food in southeast Turkey: Implications for prehistoric subsistence in Southwest Asia. In A.S. Fairbairn and E. Weiss (eds.) *From Foragers to Farmers: Papers in honour of Gordon C. Hillman*, pp. 71-85. Oxford: Oxbow.

Matthews, R.J and I. Hodder 1993 Introduction. In I. Hodder and the Çatalhöyük Research Trust (eds.). *Çatalhöyük 1993 Archive Report*. Online at http://www.catalhoyuk.com.

Matthews, R.J. 1995 Çatalhöyük 1995: surface scraping. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1995 Archive Report*. Online at http://www.catalhoyuk.com.

Matthews, W., C.A.I. French, T. Lawrence, D.F. Cutler and M.K. Jones 1996. Multiple surfaces: the micromorphology. In I. Hodder (ed.) *On the Surface: 1993*-95, pp. 301-342. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Matthews, W. 1998 Report on Sampling Strategies, Microstratigraphy and Micromorphology of Depositional Sequences, and Associated Ethnoarchaeology at Çatalhöyük. In I. Hodder and the Çatalhöyük Research Trust (eds.). *Çatalhöyük 1998 Archive Report*. Online at http://www.catalhoyuk.com.

Matthews, W. 1999 Micromorphology Archive Report. In I. Hodder and the Çatalhöyük Research Trust (eds.). *Çatalhöyük 1999 Archive Report*. Online at http://www.catalhoyuk.com.

Matthews, W. 2005a Micromorphological and Microstratigraphic Traces of Uses and Concepts of Space. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 4, pp. 355-398. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Matthews, W. 2005b Life-cycle and Life-course of Buildings. In I. Hodder (ed.) *Çatalhöyük perspectives: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 6, pp. 125-149. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Matthews, W. 2010 Geoarchaeology and taphonomy of plant remains and microarchaeological residues in early urban environments in the Ancient Near East. *Quaternary International* 214: 98-113.

Matthews, W. 2012 Household Life-histories and Boundaries: microstratigraphy and micromorphology of architectural surfaces in Building 3 (BACH). In R. Tringham and M. Stevanović (eds.) *Last House on the Hill: BACH Area Reports from Çatalhöyük, Turkey*. Los Angeles: Cotsen Institute of Archaeology Publications, University of California.

de Meester, T. (ed.) 1970 *Soils of the Great Konya Basin, Turkey*. Wageningen: Centre for Agricultural Publishing and Documentation.

Meier, U. 1999 Agricultural activities and land use in a Neolithic village around 3900 BC: Hornstaad Hörnle IA, Lake Constance, Germany. *Vegetation History and Archaeobotany* 8: 87-94.

Maier, U. 2001 *Botanische und pedologische Untersuchungen zur Ufersiedlung Hornstaad- Hörnle IA.* Stuttgart: Konrad Theiss Verlag.

Mellaart, J. 1959 Archaeological survey of the Konya Plain. *Anatolian Studies* 9: 31-33

Mellaart, J. 1962 Excavations at Çatal Hüyük, 1961. First Preliminary Report. *Anatolian Studies* 12: 41-65.

Mellaart, J. 1963 Excavations at Çatal Hüyük, 1962. Second Preliminary Report. *Anatolian Studies* 13: 43-103.

Mellaart, J. 1964 Excavations at Çatal Hüyük, 1963. Third Preliminary Report. *Anatolian Studies* 14: 39–119.

Mellaart, J. 1966 Excavations at Çatal Hüyük, 1965. Fourth Preliminary Report. *Anatolian Studies* 16: 165-91.

Mellaart, J. 1967 *Çatal Hüyük. A Neolithic Town in Anatolia*. London: Thames and Hudson.

Mellaart, J. 1970 *Excavations at Haçilar*. Edinburgh: Edinburgh University Press.

Mellaart, J. 1975 *The Neolithic of the Near East.* London: Thames and Hudson.

Meurers-Balke, J. and J. Lüning 1992 Some Aspects and Experiments Concerning the Processing of Glume Wheats. In P.C. Anderson (ed*) Prehistoire de l'Agriculture: Nouvelles Approches Experimentales et Ethnographiques*, pp. 341-362. Paris: Éditions du CNRS.

Milisauskas, S. and Kruk, J. 1989 Neolithic Economy in Central Europe. *Journal of World Prehistory* 3: 403-446.

Miller, N.F. 1984 The use of dung as fuel: An ethnographic example and an archaeological application. *Paléorient* 10: 71-79.

Miller, N.F. and T.L. Smart 1984 Intentional burning of dung as fuel: A mechanism for the incorporation of charred seeds into the archaeological record. *Journal of Ethnobiology* 4: 15-28.

Miller, N.F. 1996 Seed-Eaters of the Ancient Near East: Human or Herbivore? *Current Anthropology* 37: 521-528.

Miksicek, C. 1987 Formation processes of the archaeobotanical record. *Advances in Archaeological Method and Theory* 10: 211-247.

Moore, A. 1985 The development of Neolithic Societies in the Near East. In F. Wendorf and A. Close (eds.) *Advances in World Archaeology* 4: 1-69. New York: Academic Press.

Moore, A.M.T., G.C. Hillman and A.J. Legge 2000 *Village on the Euphrates: from foraging to farming at Abu Hureyra.* New York: Oxford University Press.

Nesbitt, M. 1995 Plants and People in Anatolia. *Biblical Archaeologist* 58 (2): 68-81.

Nesbitt, M. 2002 When and where did domesticated cereals first occur in southwest Asia? In R.T.J. Cappers and S. Bottema (eds.) *The dawn of farming in the Near East*, pp. 113-132. Berlin: Ex Oriente.

Nesbitt, M. 2006 *Identification Guide for Near Eastern Grass Seeds*. London: Institute of Archaeology, University College London.

Netting, R. McC 1990 Population, Permanent Agriculture, and Politics. In S. Upham (ed.) *The Evolution of Political Systems: Sociopolitics in Small-Scale Sedentary Societies*, pp. 21-61. Cambridge: Cambridge University Press.

Norusis, M.J. 2002 *SPSS 11.0 guide to data analysis*. New Jersey, Upper Saddle River: Prentice Hall.

Oberdorfer, E. 1994 *Pflanzensoziologische Exkursionsflora*. Stuttgart: Eugen Ulmer.

OriginLab Corporation 1991-2000. *Origin 6.1*. Northampton: OriginLab Corporation.

Özbaşaran, M. 1999 Musular: A general assessment on a new Neolithic site in central Anatolia. In M. Özdoğan and N. Başgelen (eds.) *Neolithic in Turkey, the cradle of civilization. New discoveries*, pp. 147-155. Istanbul: Arkeoloji ve Sanat Yayinlari.

Özbaşaran, M. 2000 The Neolithic site of Musular, Central Anatolia. *Anatolica* 26: 129-151.

Özbaşaran, M. and H. Buitenhuis 2002 Proposal for a regional terminology for Central Anatolia. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, pp. 67-77. Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001. Istanbul: Ege Yayınları.

Özbaşaran, M. 2011 The Neolithic on the Plateau. In S.R. Steadman and G. McMahon (eds.) *The Oxford Handbook of Ancient Anatolia: (10,000-323 Bce)*, pp. 99-124. Oxford: Oxford University Press.

Özdoğan, M. and A. Özdoğan 1989 Çayönü: a conspectus of recent work. *Paleorient* 15: 65-74.

Özdoğan, M. 1997a The beginning of neolithic economies in southeastern Europe: an Anatolian perspective. *Journal of European Archaeology* 5 (2): 1–33.

Özdoğan, M. 1997b Anatolia from the last glacial maximum to the Holocene climatic optimum: cultural transformations and the impact of the environmental setting. Paléorient 23 (2): 25–38.

Özdoğan, M. and N. Başgelen (ed.) 1999 *Neolithic in Turkey: the Cradle of Civilization* (Vol.1-2). Istanbul: Arkeoloji ve Sanat Yayinlari.

Özdoğan, M. H. Hauptmann and N. Başgelen (eds.) 2003 *Köyden Kente. Yakındoğu'da Ilk Yerleşimler. From Villages to Cities. Early Villages in the Near East* (Vol.1-2). Studies Presented to Ufuk Esin. Istanbul: Arkeoloji ve Sanat Yayınları.

Palmer, C. 1998a The Role of Fodder in the Farming System: a Case Study from Northern Jordan. *Environmental Archaeology* 1: 1-10.

Palmer, C. 1998b An exploration of the effects of crop rotation regime on modern weed floras, *Environmental Archaeology* 2: 35-48.

Payne, S. 1972 Can Hasan III, The Anatolian Aceramic and the Greek Neolithic. In E.S. Higgs (ed.) *Papers in Economic Prehistory*, pp. 191-194. Cambridge: Cambridge University Press.

Pearsall, M.D 2000 *Paleoethnobotany. A Handbook of Procedures*. Orlando: Academic Press.

Pearson, J., H. Buitenhuis, R.E.M. Hedges, L. Martin, N. Russell, K.C. Twiss 2007 New light on early caprine herding strategies from isotope analysis: a case study from Neolithic Anatolia. *Journal of Archaeological Science* 34: 2170-2179.

Peltenburg, E. 2004 Cyprus: A Regional Component of the Levantine PPN. *NeoLithics* 1 (4): 3-7**.**

Peña-Chocarro, L. 1996 *In situ* conservation of hulled wheat species: the case of Spain. In S. Padulosi, K. Hammer and J. Heller (eds.) *Hulled wheats: promoting the conservation and use of underutilized and neglected crops* IV, pp. 129-146. Rome: International Plant Genetic Resources Institute.

Peña-Chocarro, L. 1999 *Prehistoric Agriculture in Southern Spain during the Neolithic and the Bronze Age. The application of ethnographic models*. BAR International Series. Oxford: Archaeopress.

Peña-Chocarro, L. and L. Zapata Peña, L. 1999 History and traditional cultivation of *Lathyrus sativus* L. and *Lathyrus cicera* in the Iberian Peninsula. *Vegetation History and Archaeobotany* 8: 49-52.

Peña-Chocarro, L. and L. Zapata-Peña 2003 Post-harvest processing of hulled wheats. An ethnoarchaeological approach. In P.C. Anderson, L.S. Cummings, T.S. Schippers and B. Simonel (eds.) *Le Traitement desRrécoltes. Un regard sur la diversité du Néolithique au present*, pp. 99-114. Actes des XXIIIe rencontres Internationales d'archéologie et d'histoire d'Antibes, Éditions APDCA**.**

Peters, J., A. von den Driesch and D. Helmer 2005 The upper Euphrates-Tigris basin: cradle of agro-pastoralism? In J.-D. Vigne, J. Peters and D. Helmer (eds.) *The First Steps of Animal Domestication*, pp. 96-124. Oxford: Oxbow Books.

Piperno, D.R. 2006 *Phytoliths. A Comprehensive Guide for Archaeologists and Paleoecologists.* Lanham, New York, Toronto, Oxford: AltaMira Press.

Popay, I. and R. Field 1996 Grazing animals as weed control agents. *Weed Technology* 10: 217-231.

Reddy, S.N. 1999 Fueling the hearths in India: The role of dung in paleoethnobotanical interpretation. *Paléorient* 24: 61–69.

Reddy, S.N. 2003 *Discerning Palates of the Past. An Ethnoarchaeological Study of Crop Cultivation and Plant Usage in India*. International Monographs in Prehistory.

Reese, D.S. 2005 The Çatalhöyük Shells. In I. Hoddder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 4, pp. 123-127. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Renfrew, J.M 1973 *Paleoethnobotany: The Prehistoric Food Plants of the Near East and Europe*. New York: Columbia University Press.

Richards, M.P., J.A. Pearson, T.I. Molleson, N. Russell and L. Martin 2003 Stable isotope evidence of diet at Neolithic Çatalhöyük, Turkey. *Journal of Archaeological Science* 30: 67-76.

Richards, M.P. and J.A. Pearson 2005 Stable Isotope Evidence of Diet at Çatalhöyük. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 4, pp. 313-321. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

de Ridder, N.A. 1965 Sediments of the Konya Basin, Central Anatolia, Turkey. *Palaeogeography, Palaeoclimatology, Palaeoecology* 1: 225-254.

Roberts N. 1983 Age, palaeoenvironments, and climatic significance of Late Pleistocene Konya Lake, Turkey. *Quaternary Research* 19: 154-171.

Roberts, N. 1991 Late Quaternary geomorphological change and the origins of agriculture in south central Turkey. *Geoarchaeology* 6: 1-26.

Roberts, N. 1995 Climatic forcing of alluvial fan regimes during the late Quaternary in the Konya basin, south central Turkey. In J. Lewin, M.G. Macklin and J.C. Woodward (eds.) *Mediterranean Quaternary River Environments*, pp. 207-217. Rotterdam: Balkema.

Roberts, N., P. Boyer and R. Parish 1996 Preliminary results of geomorphological investigations at Çatalhöyük. In I. Hodder (ed.) *On the surface: Çatalhöyük 1993-1995*, pp. 19-40. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Roberts, N., S. Black, P. Boyer, W.J. Eastwood, H.I Griffiths, H.F. Lamb, M.J. Leng, R. Parish, M.J. Reed, D. Twigg and H. Yiğitbaşioğlu 1999 Chronology and Stratigraphy of Late Quaternary Sediments in the Konya Basin, Turkey: Results from the KOPAL Project. *Quaternary Science Reviews* 18: 611-630.

Roberts N., J. Reed, M. Leng, C. Kuzucuoğlu, M. Fontugne, J. Bertaux, H. Woldring, S. Bottema, S. Black, E. Hunt and M. Karabıyıkoğlu 2001 The tempo of Holocene climate change in the eastern Mediterranean region: new high-resolution crater-lake sediment data from central Turkey. *The Holocene* 11: 721-736.

Roberts, N., P. Boyer and J. Merrick 2007 The KOPAL On-site and Off-site Excavations and Sampling. In I. Hodder (ed.) *Excavating Çatalhöyük: South, North and KOPAL Area reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 3, pp. 553-572. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara Monograph.

Roberts, N. and A.M. Rosen 2009 Diversity and Complexity in Early Farming Communities of Southwest Asia: New Insights into the Economic and Environmental Basis of Neolithic. *Current Anthropology* 50 (3): 393-402.

Roberts, N., W.J. Eastwood, C. Kuzucuoğlu, G. Fiorentino and V. Caracuta 2011 Climatic, vegetation and cultural change in the eastern Mediterranean during the mid-Holocene environmental transition. *The Holocene* 21 (1): 147–162.

Rollefson, G.O. 1987 Local and Regional Relations in the Levantine PPN Period: 'Ain Ghazal as a Regional Centre. *Studies in the History and Archaeology of Jordan* 3: 29-32.

Rollefson, G.O. 1997 Changes in architecture and social organisation at Neolithic 'Ain Ghazal. In H.G.K. Gebel, Z. Kafafi and G.O. Rollefson (eds.) *The Prehistory of Jordan II. Perspectives from 1997*, pp. 287-308. Berlin: Ex Oriente.

Rollefson, G.O., Simmons, A. and Z. Kafafi 1992 Neolithic Cultures at 'Ain Ghazal, Jordan. *Journal of Field Archaeology* 19 (4): 443-470.

Rollefson, G.O. and I. Kohler-Rollefson 1989 The collapse of the early Neolithic settlements in the southern Levant. In I. Hershovitz (ed.) *People and Culture in Change*, pp. 73-89. BAR International Series. Oxford: Archaeopress.

Rösch, M. 1996 New Approaches to Prehistoric Land-Use Reconstruction in South-Western Germany. *Vegetation History and Archaeobotany* 5: 65-70.

Rosen, A.M. 2005 Phytolith indicators of plant and land use at Çatalhöyük. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons.* Çatalhöyük Project Vol. 4, pp. 203-212. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Rosen, A.M. and N. Roberts 2005 The Nature of Çatalhöyük: People and their Changing Environments on the Konya Plain. In I. Hodder (ed.) *Çatalhöyük perspectives: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 6, pp. 39-53. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Rosenberg, M., 1994 Hallan Çemi Tepesi: Some further observations concerning stratigraphy and material culture. *Anatolica* 20: 121–140.

Rossignol-Strick, M. 1995 Sea-land correlation of pollen records in the eastern Mediterranean for the glacial-interglacial transition: biostratigraphy versus radiometric timescale. *Quaternary Science Reviews* 14: 893-915.

Rowntree, D. 1981 *Statistics without tears: a primer for non-mathematicians*. London: Penguin Books.

Russi, P., P.S. Cocks and E.H. Roberts 1992 The Fate of Legume Seeds Eaten by Sheep from a Mediterranean Grassland. *Journal of Applied Ecology* 29 (3): 772-778.

Russell, N. 2005 Çatalhöyük worked bone. In (Ed.) Hodder I. *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*, Çatalhöyük Project Vol. 5, pp. 339-368. Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara.

Russell, N. and L. Martin 2005 Çatalhöyük mammal remains. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons.* Çatalhöyük Project Vol. 4, pp. 33-98. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Russell N. and S. Meece 2005 Animal representations and animal remains at Çatalhöyük. In I. Hodder (ed.) *Çatalhöyük perspectives: reports from the 1995-99 seasons*, Çatalhöyük Project Vol. 6, pp. 209-231. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Russell, N. and K.J. McGowan 2005 Çatalhöyük bird bones. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995–99 seasons*. Çatalhöyük Project Vol. 4, pp. 99-110. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Russell, N. 2012 Mammals from the BACH Area at Çatalhöyük. In R. Tringham and M. Stevanović (eds.) *Last House on the Hill: BACH Area Reports from Çatalhöyük, Turkey*. Los Angeles: Cotsen Institute of Archaeology Publications, University of California.

Russell, N. *et al*. in press/2013 Faunal Report. In I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Ryan, P. 2008 The Phytoliths. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2008 Archive Report*. Online at http://www.catalhoyuk.com.

Ryan, P. 2011 Plants as material culture in the Near Eastern Neolithic: perspectives from the silica skeleton artifactual remains at Çatalhöyük. *Journal of Anthropological Archaeology* 30: 292–305.

Ryan, P. in press/2013 Phytoliths. In I. Hodder (ed.) *Humans and Landscapes of Çatalhöyük: Reports from the 2000-2008 Seasons*. Los Angeles: Cotsen Institute of Archaeology, University of California at Los Angeles.

Sahlins, M.D. 1974 *Stone Age Economics*. London: Tavistock.

Savard, M., M. Nesbitt and M.K. Jones 2006 The role of wild grasses in subsistence and sedentism: new evidence from the northern Fertile Crescent. *World Archaeology* 38: 179-196.

Schiffer, M.B. 1976 *Behavioural Archaeology*. Orlando: Academic Press.

Schiffer, M.B. 1987 *Formation Processes of the Archaeological Record*. Albuquerque: University of New Mexico Press.

Schirmer 1990 Some Aspects of Buildings at the "Aceramic-Neolithic" Settlement of Çayönü Tepesi. *World Archaeology* 21: 363-387.

Shennan, S. 1997 (2nd edition) *Quantifying Archaeology*. Edinburgh: Edinburgh University Press.

Sherratt, A.G. 1980 Water, soil and seasonality in early cereal cultivation. *World Archaeology* 11: 313-330.

Sherratt, A. 2004 Fractal Farmers: patterns of Neolithic origins and dispersal. In J. Cherry, C. Scarre and S. Shennan (eds) *Explaining Social Change: studies in honour of Colin Renfrew*, pp. 53-63. Cambridge: McDonald Institute for Archaeological Research.

Sherratt, A.G. 2005 The Origins of Farming in South-West Asia, *ArchAtlas*, February 2010, Edition 4, http://www.archatlas.org/OriginsFarming/Farming.php, Accessed: 16 September 2012.

Sherratt, A.G. 2007 Diverse origins: regional contributions to the genesis of farming. In S. Colledge and J. Conolly (eds.) *The Origins and Spread of Domestic Plants in Southwest Asia and Europe*, pp. 1-20. London: Institute of Archaeology, University College London.

Shillito, L.M., W. Matthews and M.J. Almond 2008 Investigating midden formation processes and cultural activities at Neolithic Çatalhöyük, Turkey. *Antiquity* 82 (317): Project Gallery. (http://antiquity.ac.uk/projgall/shillito/index.htm)

Shillito, L-M. and M.J. Almond 2010 Comment on: Fruit and seed biomineralization and its effect on preservation by E. Messager *et al*. *Archaeological and Anthropological Sciences* 2: 25-34.

Sidell, E.J. and C. Scudder 2005 The eggshell from Çatalhöyük. In I. Hodder (ed.) *Inhabiting Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 4, pp. 117-121. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Silvertown, J.W. 1981 Seed Size, Life-Span, and Germination Date as Co-Adapted Features of Plant Life-History. *American Naturalist* 118: 860-864.

Simmons, A. 2000 Villages on the edge: regional settlement change and the end of the Levantine Pre-Pottery Neolithic. In I. Kuijt (ed.) *Life in Neolithic farming communities; social organisation, identity and differentiation*, pp. 211-234. New York: Kluwer Academic.

Simmons, A. 2007 *The Neolithic Revolution in the Near East*. Tucson: University of Arizona Press.

Smilauer, P. 1992 *CANODRAW 3.0 User's Guide*. London.

Smith, A. 2005 *Climate, Culture, and Agriculture: Examining Change in the Near East during the Bronze and Iron Ages*. Unpublished Ph.D dissertation. Boston University, Boston, MA.

Sodarak, H. 1999 *Shifting cultivation practices by Hmong, Khamu and Lao ethnic categories in the Nam Nane Watershed, Nane District, Luang Prabang Province, Lao PDR*. Unpublished Master Thesis. Swedish University of Agricultural Sciences, Department of Rural Development Studies., Uppsala.

van Soest, P.J. 1987 (2nd edition) *Nutritional ecology of the ruminant***.** Cornell University Press.

Stevanović, M. 1997 The Age of Clay: The social dynamics of house destruction. *Journal of Anthropological Archaeology* 16: 334-395.

Stevanović, M. and R.E. Tringham 1998 The BACH 1 Area. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1998 Archive Report*. Online at http://www.catalhoyuk.com.

Stevanović and St. George 2005 Architecture. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2005 Archive Report*. Online at http://www.catalhoyuk.com.

Stevens, C.J. 2003 An investigation of consumption and production models for prehistoric and Roman Britain, *Environmental Archaeology* 8: 61-76.

Stone, K.R. 2010 *Polygonum aviculare*. In: *Fire Effects Information System*. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Online at: http://www.fs.fed.us/database/feis/.

Tağı, S.Ö. and C.A. Jirousek 2005. Community, identity and dress in the Azdavay region of Black Sea Turkey. In Marchese, R.T. (ed.) *The Fabric of Life: cultural transformations in Turkish Society*, 225-240. Binghamton: Global Academic Publishing.

ter Braak, C.F.J. and P. Smilauer 1997-1999 *CANOCO for Windows version 4.02*. Wageningen: Centre for Biometry.

Thissen, L. 2002 Time trajectories for the Neolithic of Central Anatolia. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, pp. 13-26. Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001. Istanbul: Ege Yayınları.

Thomas, B. 1993 The molecular biology of flowering. In B.R. Jordan (ed.) *Internal and external controls on flowering*, pp. 1-19. Wallingford: CAB International.

Thomas, B., I. Carré and S. Jackson 2006 Photoperiodism and Flowering. In. B.R. Jordan (ed.) *The Molecular Biology and Biotechnology of Flowering*, pp. 3-25. Wallingford: CABI.

Todd, I.A. 1976 *Çatal Hüyük in Perspective*. Menlo Park (CA): Cummings.

Townsend, C.C. and E. Guest (eds.) 1966-1985 *Flora of Iraq*, Vol. 2-8. Baghdad: Ministry of Agriculture and Agrarian Reform.

Tringham, R. and M. Stevanović (eds.) 2012 *Last House on the Hill: BACH Area Reports from Çatalhöyük, Turkey*. Los Angeles: Cotsen Institute of Archaeology Publications, University of California.

Tung, B. 2005 A Preliminary Investigation of Mudbrick at Çatalhöyük. In I. Hodder (ed.) *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 5, pp. 215-219. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Turner, R., N. Roberts, W.J. Eastwood, E. Jenkins, E. and A. Rosen 2010 Fire, climate and the

origins of agriculture: micro-charcoal records of biomass burning during the last glacial-interglacial transition in Southwest Asia. *Journal of Quaternary Science* 5 (3): 371-386.

Twiss, K.C. 2007 Home is where the hearth is: food and identity in the Neolithic Levant. In K.C. Twiss (ed.) *The archaeology of food and identity*, pp. 50-68. Carbondale, Illinois: Center for Archaeological Investigations, Southern Illinois University Carbondale.

Twiss, K.C., A. Bogaard, D. Bogdan, T. Carter, M.P. Charles, S. Farid, N. Russell, M. Stevanović, E.N. Yalman and L. Yeomans 2008 Arson or Accident? The Burning of a Neolithic House at Çatalhöyük. *Journal of Field Archaeology* 33 (1): 41-57.

Twiss, K.C., A. Bogaard, M.P. Charles, J. Henecke, N. Russell, L. Martin and G. Jones 2009 Plants and animals together: Interpreting organic remains from Building 52 at Çatalhöyük. *Current Anthropology* 5: 885–895.

Ünal, H.G. and K. Sacilik 2011 Milling quality of hulled wheat bulgur with stone mill. *Journal of Food Process Engineering* 34: 893–904.

Ullrich, S.E. 2011 *Barley: Production, Improvement and Uses*. World Agriculture Series. Wiley-Blackwell.

Valamoti, S-M. and M. Charles 2005 Distinguishing food from fodder through the study of charred plant remains: an experimental approach to dung-derived chaff. *Vegetation History and Archaeobotany* 14: 528-533.

Valamoti, S-M. 2007 Detecting seasonal movement from animal dung: an investigation in Neolithic northern Greece. *Antiquity* 81 (314): 1053-1064.

Valamoti, S-M., K. Moniaki and A. Karthanou 2010 Processing and Consumption of pulses in Prehistoric Greece: archaeobotanical, experimental and ethnographic evidence. Paper presented at the *15th Conference of the International Work Group for Palaeoethnobotany*, Wilhemshaven, Germany.

van der Veen, M. and N. Fieller 1982 Sampling seeds. *Journal of Archaeological Science* 9: 287-298.

van der Veen, M. 1992 *Crop husbandry regimes. An archaeobotanical Study of Farming in northern England 1000 BC - AD 500.* Sheffield: Sheffield Archaeological Monographs 3.

van der Veen, M. 2005 Gardens and fields: the intensity and scale of food production. *World Archaeology* 37: 157-163.

van der Veen, M. and G. Jones 2006 A re-analysis of agricultural production and consumption: implications for understanding of the British Iron Age. *Vegetation History and Archaeobotany* 15: 217-228.

van der Veen, M. 2007 Formation processes of desiccated and carbonised plant remains - the identification of routine practice. *Journal of Archaeological Science* 34: 968-990.

Villalba, J. J. and F.D. Provenza 2009 Learning and Dietary Choice in Herbivores. *Rangeland Ecology and Management* 62 (5): 399-406**.**

Vita-Finzi, C. 1969 *The Mediterranean Valleys.* Cambridge: Cambridge University Press.

Wallace, M. 2007 Ethnoarchaeological work on sheep dung and application to selected samples from Çatalhöyük. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 2007 Archive Report*. Online at http://www.catalhoyuk.com.

Wallace and Charles in press What goes in doesn't always come out: the impact of ruminant digestion on plant material and its importance for the interpretation of dung-derived archaeobotanical assemblages. *Environmental Archaeology*.

Wasylikowa, K. 1981 The Role of Fossil Weeds for the Study of Former Agriculture. *Zeitschrift für Archäologie* 15: 11-23.

Watkins, T. 1996 Excavations at Pınarbaşı: the early stages. In I. Hodder (ed.) *On the Surface: Çatalhöyük 1993-95*, pp. 47-57. Cambridge: McDonald Institute for Archaeological Research. London: British Institute of Archaeology at Ankara.

Wendrich, W. 2005 Çatalhöyük Basketry. In I. Hodder (ed.) *Changing materialities at Çatalhöyük: reports from the 1995-99 seasons*. Çatalhöyük Project Vol. 5, pp. 333-338. Cambridge: McDonald Institute Monographs. London: British Institute of Archaeology at Ankara.

Wick, L., G. Lemcke and M. Sturm 2003 Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: high-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey. *The Holocene* 13: 665-670.

Wickens, G.E. 1998 *Ecophysiology of Economic Plants in Arid and Semi-Arid Lands*. Berlin: Springer Verlag.

Willcox, G. 1992 Archaeobotanical significance of growing Near Eastern progenitors of domestic plants at Jalès (France). In P. Anderson (ed.) *Préhistoire de l'agriculture: Nouvelles approches expérimentales et ethnographiques*, pp. 159-178. Paris: Éditions du CNRS.

Willcox, G. 2002a Geographical variation in major cereal components and evidence for independent domestication events in the Western Asia. In R.T.J. Cappers and S. Bottema (eds.) *The dawn of farming in the Near East*. Studies in Near Eastern Production, Subsistence and Environment, pp. 133-140. Berlin: Ex oriente.

Willcox, G. 2002b Charred plant remains from a late tenth millennium kitchen at Jerf el Ahmar (Syria). *Vegetation History and Archaeobotany* 11: 55-60.

Willcox, G., S. Fornite and L. Herveux 2008 Early Holocene cultivation before domestication in northern Syria. *Vegetation History and Archaeobotany* 17 (3): 313-325.

Wilk, R.R. and R.M. Netting 1984 Households: changing forms and functions. In R.M. Netting, R.R. Wilk and E.J. Arnould (eds.) *Households: comparative and historical studies of the domestic group*, pp. 1-28. Berkeley: University of California Press**.**

Wilson, D.G. 1984 The carbonisation of weed seeds and their representation in macrofossil assemblages. In W.A. Casparie and W. van Zeist (eds.) *Plants and Ancient Man*: *Studies in palaeoethnobotany*, pp. 201-206. Rotterdam: Balkema.

Woldring, H. 1998 A pollen diagram from a river sediment in Central Anatolia. *TÜBA-AR* 1: 105–111.

Woldring, H. 2002 Climatic change and the onset of sedentism in Cappadocia. In F. Gérard and L. Thissen (eds.) *The Neolithic of Central Anatolia, internal developments and external relations during the 9th-6th millennia cal BC*, pp. 39-66. Proceedings of the International CANeW Round Table, Istanbul 23-24 November 2001. Istanbul: Ege Yayınları.

Woldring, H. and S. Bottema 2003 The vegetation history of East-Central Anatolia in relation to archaeology: The Eski Acıgöl pollen evidence compared with the Near Eastern environment. *Palaeohistoria* 43/44: 1-34.

Wollstonecroft, M. and A. Erkal 1999 Summary of plant-processing experiments 1999. In I. Hodder and the Çatalhöyük Research Trust (eds.) *Çatalhöyük 1999 Archive Report*. Online at http://www.catalhoyuk.com.

Wollstonecroft, M.M, P.R. Ellis, G.C. Hilllman and D.Q. Fuller 2008 Advances in plant food processing in the Near Eastern Epipalaeolithic and implications for improved edibility and nutrient bioaccessibility: an experimental assessment of *Bolboschoenus maritimus* (L.) Palla (sea club-rush). *Vegetation History and Archaeobotany* 17: 19-27.

Wollstonecroft, M., Z. Hroudová, G.C. Hillman and D.Q. Fuller 2011 *Bolboschoenus glaucus* (Lam.) S.G. Smith, a new species in the flora of the ancient Near East. *Vegetation History and Archaeobotany* 20: 459–470**.**

Wright, K.I. 2000 The social origins of cooking and dining in early villages of Western Asia. *Proceedings of the Prehistoric Society* 2: 89-122.

Wright, P. 2003 Preservation or destruction of plant remains by carbonization? *Journal of Archaeological Science* 30: 577–583.

Zeder, M.A. 2005 A View from the Zagros: new perspectives on livestock domestication in the Fertile Crescent. In J-D.Vigne, J. Peters and D. Helmer (eds.) *First Steps of Animal Domestication: New archaeozoological approaches*, pp. 125-146. Oxford: Oxbow.

Zeder, M.A. 2008 Animal domestication in the Zagros: an update and directions for future research. In E. Vila, L. Gourichon, A.M. Choyke and H. Buitenhuis (eds.) *Archaeozoology of the Near East VIII: proceedings of the 8th International Symposium on the Archaeozoology of Southwestern Asia and Adjacent Areas*, pp. 243–278. Lyon: Maison de l'Orient et de la Méditerranée.

Zeder, M.A. 2011 The Origins of Agriculture in the Near East. *Current Anthropology* 52 (Supp. 4): 221-236.

van Zeist, W. and J.A.H. Bakker-Heeres 1975 Evidence for linseed cultivation before 6000 BC. *Journal of Archaeological Science* 2: 215-219.

van Zeist, W. and J.A.H. Bakker-Heeres 1982 (1985) Archaeobotanical studies in the Levant 1. Neolithic sites in the Damascus basin: Aswad, Ghoraifé, Ramad. *Palaeohistoria* 24: 165-256.

van Zeist, W. and H. Buitenhuis 1983 A palaeobotanical study of Neolithic Erbaba, Turkey. *Anatolica* 10: 47-48.

van Zeist, W. and J.A.H. Bakker-Heeres 1984a (1986) Archaeobotanical studies in the Levant 2. Neolithic and Halaf levels at Ras Shamra. *Palaeohistoria* 26: 151-170.

van Zeist, W. and J.A.H. Bakker-Heeres 1984b (1986) Archaeobotanical studies in the Levant 3. Late-Palaeolithic Mureybit. *Palaeohistoria* 26: 171-199.

van Zeist, W., P.E.L. Smith, R.M. Palfenier-Vegter, M. Suwijn and W.A. Casparie 1984 (1986) An archaeobotanical study of Ganj Dareh Tepe, Iran. *Palaeohistoria* 26: 201-218.

van Zeist, W. and J.A.H. Bakker-Heeres 1985 Archaeobotanical studies in the Levant 4. Bronze Age sites on the North Syrian Euphrates. *Palaeohistoria* 27: 247-316.

van Zeist, W. and G.J. de Roller 1991-1992 The Plant Husbandry of Aceramic Çayönü, SE Turkey. *Palaeohistoria* 33/34: 65–97.

van Zeist, W. and G.J. de Roller 1995 Plant remains from Aşıklı Höyük, a Pre-Pottery Neolithic site in Central Anatolia. *Vegetation History and Archaeobotany* 4: 179-185.

Zohary, M. 1973 *Geobotanical foundations of the Middle East* (Vol. 1-2). Stuttgart: G. Fischer.

Zohary, D. and M. Hopf 2000 *Domestication of Plants in the Old World* (2nd edition), Oxford: Oxford University Press.

Appendix 1 Fieldwork in the Kastamonu region, North (Black Sea) Turkey

As part of an ethnoarchaeological project supported by the Fell Fund, University of Oxford, on traditional cultivation, processing and storage of cereals and pulses in various regions of Anatolia, in 2008 Çatalhöyük archaeobotany team members[1] took an exploratory trip to the region of Kastamonu to observe 'traditional' (non-mechanised) farming practices used in growing of einkorn and emmer (Bogaard *et al*. 2008). It has previously been observed that agricultural practices in rural parts of Anatolia offer valuable insight into the technological aspects of non-industrial agriculture and plant-related activities that might have also been incorporated into Neolithic every-day life (Hillman 1981, 1984a, 1985; Ertuğ-Yaraş 1997; Ertuğ 2000; Erkal 2006). The Kastamonu region of the north Turkey is one such area, where some 'ancient' wheats (einkorn and emmer) are cultivated in a more or less 'traditional' way and on a small-scale; einkorn and emmer are regularly consumed as bread or bulgur, a tradition that may be several millennia old (Hillman 1981; Ertuğ 2004a; Giuliani *et al*. 2009). The ethnographic observations of agricultural techniques, crop storage and processing in Kastamonu are described in detail elsewhere (Filipovic 2012); a brief summary is provided here.

Most of the territory of the Kastamonu province in the Black Sea region of Turkey is a harsh mountainous zone covered in forests, with most of the districts of the province situated between 600- and 1200 m elevations (Tağı and Jirousek 2005; Giuliani *et al*. 2009). Arable land used for growing hulled wheats in the Kastamonu region is limited, and the production is carried on a small-scale, seldom over the level of fulfilling the needs of individual village households (Tağı and Jirousek 2005). Though geographically a very different area to Konya plain where Çatalhöyük is located, the Kastamonu region was considered suitable for the study, given that hulled wheats were major cereal crops at the Neolithic settlement and are therefore central to interpretation of the assemblage (Fairbairn *et al*. 2005a; Bogaard *et al*. in press/2013; the present study). The fieldwork was expected to provide first-hand knowledge of on- and off-site agricultural activities. Of particular interest were a) information gathered from field-owners on the techniques used to grow and process crops, b) observation of storage

[1]The team: Dr Amy Bogaard (Oxford University), Dr Michael Charles (Sheffield University), Dr Füsun Ertuğ (Istanbul University), Dr Glynis Jones (Sheffield University), Dr Osman Tuğay (Selcuk University), Müge Ergun (Istanbul University) and Dragana Filipovic (Oxford University).

facilities and other ways of storing food in einkorn/emmer-growing villages, and c) observations of mills and other buildings/items relating to crop processing and food preparation. In addition, plant and soil samples for ongoing functional ecology[2] and isotope projects[3] (conducted at Sheffield and Oxford University respectively) were collected from the fields where no chemical fertilisers and/or herbicides area used. A list of identified arable weeds from 'organic' crop fields of relevance to weed types occurring in the Çatalhöyük assemblage is provided in Appendix I. Table 1.

The 'archaic' methods of crop cultivation and processing, recorded in parts of Anatolia, including Kastamonu, in the 1970's (Hillman 1981) have largely been replaced by agricultural machines (tractors, harvesters) generally used for field preparation and harvest. Einkorn and emmer are grown in separate fields and are processed, stored and used separately - einkorn primarily as food, while emmer is often intended as fodder for dairy cows, though preference for one or the other wheat for human consumption varies between villages in Kastamonu province (Ertuğ 2004a). Einkorn (and emmer) is threshed (mainly using threshing machines), dried and stored as spikelets, which are then dehusked and ground in water-powered mills, then fine-sieved/winnowed to remove chaff; the flour is used to make different kinds of bread. For bulgur preparation, the spikelets are parboiled, dried and taken to a mill to be cracked, and then sieved and/or winnowed to remove the husk. Processed crops are stored (as spikelets, bulgur, or flour) for subsequent consumption, while part of the yield is kept in the spikelet for seed corn (thus, sowing of spikelets rather than clean grain is practiced).

A range of 'storage situations' was encountered in the Kastamonu villages: from large-scale storage in purpose-built buildings adjacent to houses (*ambar*) to relatively small wooden boxes inside houses (*sandık*). The large built storage facilities usually represent double-storey wooden buildings with the main storage space comprising sizeable compartments extending over both levels; the compartments are entered from the top level (from above) and are used for separate storage of einkorn and emmer spikelets. Wooden chests for additional storage are located on the upper storey, while other plant products such as fruits and vegetables are sometimes spread on the floor or hung on the walls. Apparently, the quantities of stored wheat are well beyond average family requirements, but this is due to the fact that a considerable part of the produce is fed to dairy cows. Inside houses crops are stored in wooden

[2]http://www.sheffield.ac.uk/archaeology/research/fibs
[3]http://planetearth.nerc.ac.uk/features/story

Taxa	Growth stage
Adonis	Pod
Alium	Flower
Anagallis	Pod
Anagallis foemina	Vegetative, flower, pod
Anagallis , narrow leaf	Pod
Anthemis (scabiosa)	Pod
Asperula	Pod
Avena	Pod
Bifora	Pod
Bilderdykia convolvulus	Flower, pod
Boraginaceae	Vegetative
Boraginaceae/Scrophulariaceae (yellow)	Flower, pod
Buglossoides arvensis	Vegetative, pod
Bupleurum	Pod
Caryophyllaceae	Pod
Caryophyllaceae , small	Flower, pod
Centaurea	Flower, pod
Centaurea cyanus	Vegetative, flower, pod
Centaurea solstitialis	Pod
Cerastium	Pod
Chenopodium	Flower, pod
Chenopodium album	Pod
Chenopodium vulvaria	Flower, pod
Cichorium	Vegetative, flower, pod
Cirsium	Vegetative, flower, pod
Cirsium arvensis	Vegetative, flower, pod
Compositae	Vegetative
Compositae rosette	Vegetative
Compositae , hairy	Vegetative
Compositae , leafy	Vegetative
Compositae , narrow leaf	Vegetative
Compositae , oval leaf	Vegetative
Compositae/Crucifereae	Pod
Conium	Vegetative, flower, pod
Consolida orientalis	Flower, pod
Convolvulus (arvensis)	Vegetative, flower, pod
Convolvulus , large	Vegetative
Coronilla scorpioides	Pod
Crucifereae	Flower, pod
Crucifereae , small	Flower
Cynodon	Pod
Echium	Flower, pod
Eryngium	Vegetative, pod
Euphorbia , big (leafy)	Vegetative, flower, pod
Euphorbia , small	Vegetative, flower
Fumaria	Vegetative
Galium (aparine?)	Pod
Galium tricornutum	Pod
Geranium	Vegetative, flower, pod
Kickxia	Pod
Labiateae rosette	Vegetative

Taxa	Growth stage
Lactuca	Vegetative, flower, pod
Lamium	Flower, pod
Lapsana	Flower
legume	Flower, pod
Liliaceae	Pod
Lithospermum	Pod
Lolium	Pod
Lolium cf. *temulentum*	Pod
Lotus (serrated leaf)	Vegetative
Malva	Vegetative
Medicago	Vegetative
Medicago lupulina	Flower, pod
Medicago sativa	Vegetative, flower, pod
Medicago type	Vegetative, flower
Medicago , leafy	Vegetative
Melilotus , type 1	Flower, pod
Melilotus , type 2	Pod
Myosotis	Vegetative
Orlaya	Pod
Ornithogalum	Pod
Papaver rhoeas	Flower
Phalaris	Flower, pod
Plantago	Flower
Plantago , broad leaf	Pod
Polygonum aviculare	Vegetative, flower, pod
Potentilla	Vegetative
Ranunculus arvensis	Pod
Raphanus (raphanistrum)	Pod
Reseda	Flower, pod
Rhinanthus	Flower
Sanguisorba	Vegetative, pod
Scandix	Pod
Setaria	Flower
Silene vulgaris	Pod
small vetch *(Trigonella)*	Pod
Sonchus	Vegetative, flower, pod
Sonchus asper	Vegetative, flower, pod
Thymelea	Flower, pod
Tragopogon	Vegetative, flower, pod
Trifoliate	Vegetative
Trifolium	Flower, pod
Trifolium pratense	Vegetative
Trifolium type	Vegetative
Turgenia (/Caucalis)	Flower, pod
Umbellifereae , large seeded	Pod
Umbellifereae , serrated leaf	Flower
Vaccaria pyramidata	Pod
Vicia	Vegetative
Vicia cracca	Vegetative, pod
Vicia sativa	Vegetative, pod
Vicia type	Vegetative

Appendix I. Table 1 A preliminary list of weed taxa collected in einkorn and emmer fields in Kastamonu, Turkey

chests/crates as grain in the spikelet, cleaned grain and flour, and are used as and when needed. Despite the apparently restricted capacity of these features (e.g. wooden box of about 500 kg capacity is commonly used for keeping flour), the quantities of stored plant products are relatively high compared to large-scale storage, and this is again because some of the semi-clean grain (grain in the spikelet) is fed to animals. Small-scale storage to be shared within a household is characteristic of subsistence families, in contrast to farmers producing for sale as well as for their own use. The small-scale nature of plant storage also extends to vegetables grown in gardens near houses and fruits and nuts grown in orchards or collected from the wild. These products are in different ways stored for the use in winter, e.g. as underground storage of potatoes and carrots in large pits near houses, pickled vegetables, and dried and/or conserved fruits.

In terms of the structures related to crop processing, the team had a rare opportunity to observe a wheat mill (*bulgurhane* - Ertuğ-Yaraş 1997*)* and a flax (linseed) oil mill (*bezirhane* - Ertuğ-Yaraş 1997); both mills were in use and the processing was demonstrated by the village people. Overall, the number of existing traditional mills in Kastamonu and elsewhere in Turkey is low and few of them are functional.

The observation of agricultural routine in Kastamonu provided clues on the social aspect of farming, as some stages in the process involve social interaction among those doing the work. For example, individual households usually help each other in seasons of 'heavy' labour, e.g. at harvest time, which is an opportunity for them to exchange knowledge, news, and experience. Furthermore, as well as the food procurement and processing, eating also has social meanings, and family-based meals are of considerable importance. Food can be understood as a social category, and wheat-based food, particularly bulgur, has a specific role in local cuisine in much of Turkey – for example, it has been estimated that the average annual consumption of bulgur in Turkey is approximately 12 kg per person (Ünal and Sacilik 2011: 894).

Although it is not always possible to make meaningful comparisons between the present-day agricultural practices and those suggested for the past, some important similarities and differences between the Neolithic and present-day contexts have been revealed. For example, comparison of the archaeological storage evidence with the ethnographic examples suggests comparable 'pantry' (small-scale) storage for daily consumption within the household over

the year; also, wild plant collection and agricultural production are not mutually exclusive and wild and 'domestic' foods are often kept in the same storage area. Houses at Çatalhöyük display significant variation in bin capacity as do present-day farming households in Turkey, depending on the life history of the occupying family and the intended use of the products (e.g. to be sold at markets/in shops - Giuliani *et al*. 2009). On the other hand, the main contrast between the archaeological and ethnographical situation is reflected in the large-scale storage capacities for surplus crops in Kastamonu; no evidence of any large built structure intended for crop storage, or of large-scale storage in general, has been found at Çatalhöyük. This major difference could be a result of relatively small scale of manual cultivation at the site; it is also likely that storage practices were linked with social factors (e.g. Bogaard *et al*. 2009; Twiss *et al*. 2009).

Appendix 2 Experimental measuring of 'winnowability' of wild seeds

For the purpose of crop processing analysis of the wild/weed assemblage, the taxa were classified based on physical characteristics of relevance to the four main crop cleaning stages - threshing, winnowing, coarse sieving, and fine sieving, as suggested by Jones (1984, 1987). The most efficient winnowing method, as shown in a number of ethnographic case studies, is by tossing threshed crop material in a light breeze, often using a winnowing fork. In this process, light chaff, straw and weed seeds are carried aside by the breeze, while grain, heavy weed seeds, heavier chaff and straw fragments fall straight downwards (Hillman 1981, 1984b; Jones 1984; Peña-Chocarro 1999; D'Andrea and Mitiku 2002).

In order to distinguish between seeds light enough to be removed in the initial (winnowing) stage of crop processing sequence, and those that are heavy and remain with the cereal grain (considered 'heavy') to be removed in later stages (i.e. sieving, hand-cleaning), the aerodynamic properties of seeds of the identified wild/weed taxa was explored experimentally for the cases where no information could be found in the published sources. Previous experimental work by Bogaard (2004a: Appendix) has shown that seed velocity can be taken as a proxy for measuring seed 'winnowability': seeds of taxa classified as 'light' in the ethnographic study conducted by Jones (1984) at the Greek island of Amorgos have velocities lower than 3.50 m/s, and those classified as 'heavy' (i.e. that did not tend to be winnowed off in the Amorgos study) have velocities greater than 3.00 m/s. The experiment was carried out using the seed buoyancy machine set up at the Department of Archaeology, Sheffield University. This machine measures the speed of an object (seed) dropped down a tube from a certain height (*c*. 2 m); at the base of the tube, a box with two built-in lasers registers falling objects and provides immediate information on their velocity (Askew *et al*. 1997). The same machine was used in this study. The seeds were dropped through the machine and the goal was to obtain at least three, ideally five velocity values for each desired taxon (or the closest 'match'). The results are presented in Appendix II. Table 1; mean (and median) values were used as a basis for classification. Some types were measured as seed, seed in chaff and/or chaff only (e.g. *Taeniatherum* where both seed and chaff were found). The taxa with average seed velocities smaller than 3.00 m/s were considered 'light', and those with velocities greater than 3.50 m/s were classified as 'heavy'; species with velocities between 3.00 and 3.50 m/s were compared by morphology and size to the 'known' categories, and classified accordingly.

Genus/species	in place of	plant part	Class	MEAN value*	MEDIAN value*	drop 1	drop 2	drop 3	drop 4	drop 5
Alisma plantago-aquatica	*Alisma*	seed	LIGHT	*1.48*	*1.26*	1.74	1.72	1.55	0.77	1.63
Puccinellia koeieana	*Crypsis, Aeluropus*	seed in chaff	LIGHT	*1.54*	*1.48*	1.37	1.13	1.82	1.79	1.57
Puccinellia koeieana	*Crypsis, Aeluropus*	naked seed	LIGHT	*1.66*	*1.66*	1.48	1.41	2.17	1.15	2.07
Artemisia vulgaris	*Artemisia*	capsule	LIGHT	*1.43*	*1.28*	1.20	1.62	0.71	1.85	1.76
Artemisia vulgaris	*Artemisia*	seed	LIGHT	*1.74*	*1.64*	1.59	1.85	1.97	2.07	1.21
Eragrostis minor	*Eragrostis*	seed in chaff	LIGHT	*1.43*	*1.39*	1.46	1.40	1.50	1.26	1.51
Eragrostis minor	*Eragrostis*	naked seed	LIGHT	*2.34*	*2.32*	2.10	2.38	2.48	2.53	2.19
Helianthemum ledifoilum	*Helianthemum*	seed	LIGHT	*2.34*	*2.31*	2.31	2.31	2.08	2.48	2.53
Phleum paniculatum	*Sporobolus*	seed in chaff	LIGHT	*2.07*	*2.11*	1.91	2.31	2.10	2.08	1.94
Phleum paniculatum	*Sporobolus*	naked seed	LIGHT	*2.45*	*2.45*	2.48	2.38	2.36	2.48	2.53
Taeniatherum caput-medusae	*Taeniatherum*	chaff only	LIGHT	*2.45*	*2.44*	2.43	2.55	2.40	2.03	2.84
Juncus sp.	*Juncus*	seed	LIGHT	*1.05*	*1.05*	1.06	0.94	1.02	1.09	1.15
Juncus sp.	*Juncus*	capsule	LIGHT	*2.67*	*2.61*	2.66	3.01	3.05	2.17	2.48
Thymelea passerina	*Thymelea*	seed in pod	HEAVY	*3.05*	*3.01*	3.57	2.91	3.33	3.01	2.45
Thymelea passerina	*Thymelea*	naked seed	HEAVY	*3.39*	*3.36*	3.68	3.85	2.98	3.57	2.87
Taeniatherum caput-medusae	*Taeniatherum*	seed in chaff	HEAVY	*3.09*	*3.14*	2.63	2.75	2.43	3.79	3.85
Taeniatherum caput-medusae	*Taeniatherum*	naked seed	HEAVY	*3.59*	*3.60*	3.57	3.68	3.73	3.47	3.52
Taeniatherum caput-medusae	*Taeniatherum*	seeds in chaff with awns	HEAVY	*4.15*	*4.04*	4.31	3.91	4.46	4.46	3.62
Stachys/Lamium	*Sideritis*	seed	HEAVY	*3.12*	*3.44*	2.78	2.94	4.10	2.84	2.94
Suaeda maritima	*Suaeda*	seed in pod	HEAVY	*3.12*	*3.04*	3.38	3.05	3.25	2.69	3.25
Phalaris aquatica	*Cornucopiae*	naked seed	HEAVY	*3.17*	*3.14*	3.25	3.33	2.94		
Cardaria droba	*Conringia*	twin pod	HEAVY	*3.39*	*3.37*	3.33	3.73	3.01	3.21	3.68
Cardaria droba	*Conringia*	seed	HEAVY	*3.79*	*3.72*	4.03	3.57	3.91	3.33	4.10
Carex sp.	*Carex*	seed	HEAVY	*3.48*	*3.49*	3.52	3.47	3.68	3.42	3.29
Suaeda maritima	*Suaeda*	naked seed	HEAVY	*3.49*	*3.48*		3.52	3.62	3.33	
Alopecurus myosuroides	*Cornucopiae*	naked seed	HEAVY	*3.50*	*3.39*	3.85	3.73	2.92		
Salsola kali	*Salsola*	seed in pod	HEAVY	*3.58*	*3.63*	3.52	3.73	3.57	3.57	3.52
Salsola kali	*Salsola*	seed	HEAVY	*3.58*	*3.65*	3.38	3.38	3.73	3.91	3.52
Boreava orientalis	*Boreava*	in a pod	HEAVY	*4.41*	*4.45*	4.39	4.46	4.31	4.72	4.17
Beta vulgaris	*Beta*	pod	HEAVY	*4.51*	*4.48*	4.55	4.72	4.24	4.39	4.63
Polygonatum	*Polygonatum*	seed	HEAVY	*4.94*	*4.91*	4.90	5.00	4.81	5.00	5.00

***** Mean value = drop 1+drop 2+....+drop 5 divided by 5 (or 3 where appropriate)

* Median value = minimum value+maximum value divided by 2

Appendix II. Table 1 Determining seed winnowability using seed velocities measured by the seed buoyancy machine