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EARLY AGRICULTURE IN NORTHERN SYRIA:
BOTANICAL REMAINS FROM JERABLUS TAHTANI

A thesis submitted to the Committee on Graduate Studies in partial fulfilment of the Requirements for the Degree of Master of Arts in the Faculty of Arts and Science

TRENT UNIVERSITY

Peterborough, Ontario, Canada

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ABSTRACT:

Early Agriculture in Northern Syria: Botanical Remains from Jerablus Tahtani

Ceren Kabukcu

This thesis reports on the analysis of seed macroremain samples dating to the Late Chalcolithic and Early Bronze Age from Jerablus Tahtani located in present day northern Syria. Detailed numerical and statistical analyses were used to evaluate the relative importance of crop species in addition to an examination of the weed ecology. In doing so, possible patterns in agricultural strategies and crop use were evaluated taking into consideration environmental/climatic changes and socio-cultural shifts.

Keywords: Archaeobotany, Near East, Late Chalcolithic, Early Bronze Age

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Chapter 1. Introduction

Jerablus Tahtani lies on the east bank of the Euphrates River in northern Syria. It is a tell site occupied from the Late Chalcolithic to the Islamic period, with a hiatus from the end of the Early Bronze Age to the beginning of the Iron Age. The site displays a growth in settlement size with a rising elite by the beginning of the Early Bronze Age (Peltenburg 2007a). In order to understand the dynamics of the evolving agropastoral economy at this site, in relation to overall developments in the Near East, macroremain analysis was carried out on botanical samples dating to the Late Chalcolithic and Early Bronze Age periods.

The Chalcolithic and the Bronze Age periods in the Near East represent a dynamic time period in terms of socio-political shifts and important changes in subsistence and economy (Cooper 2006). However, the spectrum of plant exploitation during these time periods is poorly understood and several authors mention the necessity of further botanical analyses in order to address the dynamics of developing urban economies in detail (Riehl 2009, Smith 2005, McCorriston and Weisberg 2002). One of the highly debated topics in Near Eastern archaeology is concerned with the effects of environmental change on rising urban populations, especially along the Euphrates River (cf. Kuzucuoğlu and Marro 2007).

More specifically, there has been much debate and research directed towards explaining the shifts, and possible collapse, in urban settlements that occurred at the end of the Early Bronze Age, coinciding with an abrupt climatic change event that led to drier conditions across the Near East (Kuzucuoğlu and Marro 2007). In this respect, it is the aim of this thesis to add to the existing body of ecofactual data from the region dating to the time period, in addition to evaluating site-specific factors that might have led to the abandonment of the settlement. Macroremain analysis for these purposes allows for the evaluation of the crop economy in addition to the evaluation of environmental conditions indicated by wild and weedy plant species in archaeobotanical samples.

As will be discussed in Chapter 2, the region displays important changes during the Late Chalcolithic and the Early Bronze Age. The onset of metalworking during the Chalcolithic further develops into specialized craft production, while the earliest urban centers are established across the Near East (Akkermans and Schwartz 2003). This is followed by a series of larger and smaller states forming with clear indications for a developing elite class (Cooper 2006). During this time period, agricultural production is at the forefront of all discussions surrounding state formation due to the need for a surplus that could sustain populations of craftsmen and laborers in addition to an elite class. However, as mentioned already, detailed botanical analyses are much needed in the region.

With the onset of the Early Bronze Age, several sites across the Near East reflect greater trade connections, an increase in urban development, and the beginning of bronze working, an increase in the use of animal labor for agricultural production and a greater focus on livestock herding (Cooper 2006, Sherratt 1981, Fall *et al.* 2002). The urban development in the region is often interpreted as the outcome of intensified or extensified agricultural economies due to the need for surplus production. Both of these systems provide potential for an increase in production output: while intensification requires more human labor input per production unit, extensification decreases the amount of human labor input per production unit (Grigg 1984:49). For these reasons, the Early Bronze Age and the onset of urbanism is considered to reflect a resource maximization effort, where the use of livestock wool, hide, and milk, along with animal labor in sowing and harvesting and livestock assisted crop processing are interpreted as the onset of an extensification period in agricultural history (McCorriston 1997). Meanwhile, irrigation systems and hand processing of crops (i.e. grinding, pounding) are interpreted as resource intensification (Bogaard 2004).

Across the Near East, the prominence of barley in crop assemblages is interpreted as either a strategy in climatic crises due to the drought tolerant nature of the taxon, or as an intensification measure due to the salinization tolerance of the taxon in soils where irrigation is practiced (Riehl 2009). In this research project the relative abundance and inferred importance of major crops, especially of cereal grain crops will be evaluated at Jerablus, in order to address a range of questions related to choice of crop species and changes in the agricultural economy over time.

Below are listed the main research questions that guide this thesis. In order to address these questions, an exploratory and inductive approach was taken given the nature of the botanical data. The methods used in the laboratory analysis of the chosen samples the treatment of the raw data, and the statistical techniques employed are discussed in Chapter 4.

Research Questions:

- What are the patterns in crop production at the site?
- Are there any changes in cultivated plant species during the transitionary time period between the Late Chalcolithic and Early Bronze Age?
- What are the ecological conditions around the site?

- Are there any patterns in ecological conditions and environmental/climatic events at the site?

In order to assess the presence of patterning, Correspondence Analysis was used as a statistical tool that allows for the visualization of patterning in complex datasets and has been applied to various archaeobotanical and ecological data in the past (Colledge 2001, Bogaard 2004). The results of analyses and a description of samples along with context-specific descriptions can be found in Chapter 5. A full discussion of these results with relation to site-specific dynamics, and regional evaluation of trends can be found in Chapter 6. A thorough discussion of taphonomic and site formation processes that shape archaeobotanical remains can be found in Chapter 3. A summary of the results and discussions along with regional implications and suggestions for future research can be found in Chapter 7.

The next chapter is dedicated to the description of socio-political, cultural, and environmental developments in the region from the Chalcolithic and the Early Bronze Age periods. In addition, a summary is provided of previous research published on Jerablus Tahtani.

Chapter 2: Environmental, Climatic, and Socio-cultural setting of the Carchemish Sector during the Late Chalcolithic and the Early Bronze Age

2.1 Introduction

The Late Chalcolithic and Early Bronze Age (ca. 4000-2000 BC) in the Near East, and more specifically in the Middle Euphrates Valley (Figure 2.1), was a time of increasing socio-cultural complexity. Evidence to be presented below also suggests that it was also a time of increasing environmental stress on populations. As will be discussed in this chapter, the region goes through two pronounced periods of urbanization, each resulting in a higher degree of socio-political complexity and eventually ending in a varied process of decline. The first cycle of urbanism, the Uruk (after 4000 BC) and the rise of the earliest states in the region, comes to a close with the disappearance of this culture and in some cases with the abandonment of major urban centers towards the end of the Late Chalcolithic (ca. 3100 BC). In Northern Syria, the second cycle, beginning in the latter half of the Early Bronze Age (after 3100/3000 BC), sees the rise of an elite class and a multi-tiered polity system, and is contemporary with the Jemdet Nasr Period in southern Mesopotamia. Both of these surges of urbanism end in the abandonment urban centres, however it is important to note that cultural developments are not reversed; instead there is a complex process in which populations move across the landscape and shift in structure, but not to a point of deterioration. On the other hand, beginning with the Late Chalcolithic period, there is an overall tendency in the climatic record towards aridity (i.e. the 4.2 kya event ~2200 BC, Kuzucuoğlu 2007), and marginal regions experience the results of these events more dramatically (Vörösmarty *et al.* 2000). At the moment, some of the most important research questions in prehistoric archaeology of the Euphrates Valley are concerned with the explanations and implications of climate change that took place during the Late Chalcolithic and Early Bronze Age (Peltenburg 2007a).

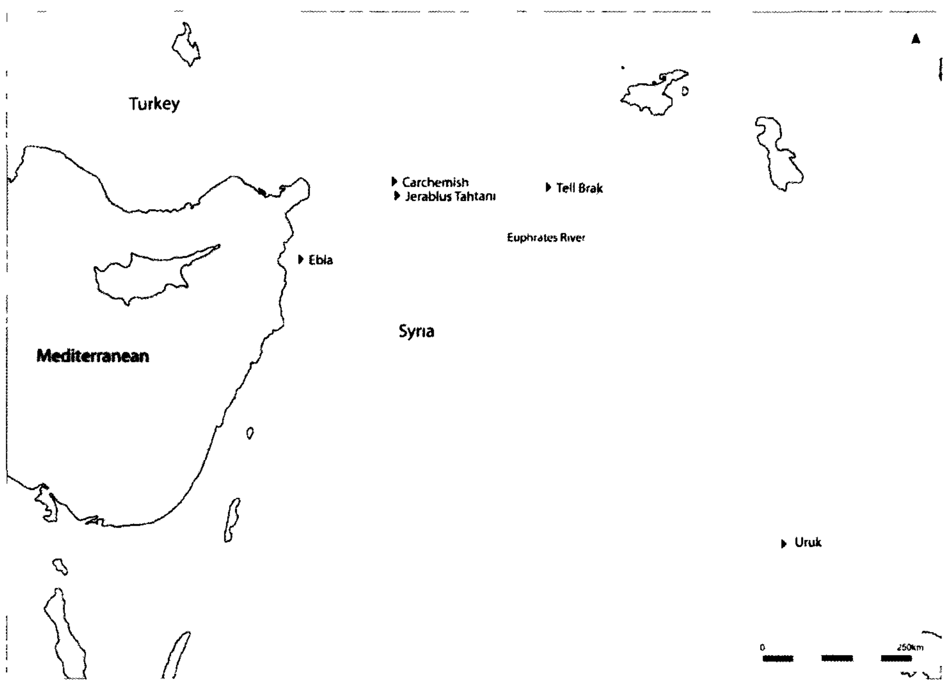

Figure 2.1 Map showing the location of Jerablus Tahtani

It is the aim of this chapter to outline the major socio-cultural developments in relation to the Euphrates valley in order set the background for further analyses. As noted by many scholars, the beginning of agricultural intensification and/or extensification in the region strongly correlates with the rise of states and increasing complexity (Akkermans and Schwartz 2003: 187, Kuhrt 1995: 23, Sagona and Zimansky 2009: 162). The role of early agricultural practices in early state formation is undeniably important. In order to assess more the nature of early agricultural processes, it is essential to evaluate relevant archaeobotanical data, its spatial and temporal distribution, and at the same time consider environmental and socio-cultural changes that are taking place within this context. To this end, there is also a short summary provided here on the relevant proxy data indicative of climatic change and a short summary on the previous botanical analyses carried out in the region.

2.2 Socio-cultural setting

The Chalcolithic and Bronze Age in the Near East signify periods of increasing socio-political complexity, with the Late Chalcolithic and the Early Bronze Age marking the earliest state formations in the region (Akkermans and Schwartz 2003: 181). There is however very little consensus on dates and relative chronology and most often periods are defined based on ceramic traditions with time periods representing overlapping periods of cultural horizons (Sagona and Zimansky 2009: 178, Bruins 2001). In this regard, studies in the Middle Euphrates Valley reflect a divide in archaeological discussion due to the fact that the region spreads over two countries (Peltenburg 2007b). Certain analyses of the region's chronology specifically relevant to the Chalcolithic and the Bronze Age stop at the border, for instance Algaze's survey of the dam areas in the Middle Euphrates Valley stop at the northern side of the border (Algaze *et al.* 1994) while other general works in the region's chronology like Akkermans and Schwartz (2003) stay on the Syrian side of the border and Sagona and Zimansky (2009) stay on the Turkish side of the border. This artificial divide further eliminates coherence on issues of chronology and leads to disagreements on the relative dating of critical events such as the 4.2 kya climate change event. There has been considerable effort to this end in the last decade with the establishment of the 'Associated Regional Chronologies for the Ancient

Near East' (ARCANE) project and the publications of such volumes that combine evidence from either side of the border (cf. Peltenburg 2007b).

On the other hand, the use of terminology in the region to describe ceramic traditions as the precursor to cultural horizons (see discussion in Cooper 2006:6-8), and a reluctance to incorporate systematic radiocarbon dating to the determination of time periods (see discussion in Bruins 2001) has led to a plethora of chronological sequences with minor variations amongst them.

2.2.1 Late Chalcolithic/Uruk

During the Early and Middle Chalcolithic (ca. 5200-4000 BC: Akkermans and Schwartz, 2003: 154, also referred to as the Ubaid cultural horizon), the Syrian Euphrates sectors are characterized by egalitarian small-scale settlements, and very little evidence for status differentiation (Akkermans and Schwartz 2003: 155, Ur 2009). The Late Chalcolithic dates roughly to 4000-3100 BC (Akkermans and Schwartz 2003: 183) and represents a change in social organization across the Near East, most markedly seen in the Euphrates Valley (Sagona and Zimansky 2009: 145, Akkermans and Schwartz 2003: 184). It is during the Late Chalcolithic that a cultural horizon known as the Uruk spread through northern Mesopotamia and Syria (Sagona and Zimansky: 145). The city of Uruk in southern Mesopotamia is used to define a cultural period in most of the Euphrates Valley and is considered to be one of the earliest cities in the Near East (Ur 2010). Attesting to the widespread influence of the Uruk political system, the Late Chalcolithic in Mesopotamia is often referred to as the Uruk period. During this period there is evidence for the emergence of centralized power, manifest with the appearance of large cities connected to smaller settlements through networks of exchange (Algaze 2001, 2008: 65, Akkermans and Schwartz 2003: 184, 197, Cooper 2006: 8). It is noted that during this time period craft specialization and standardization of economic exchange follows the introduction of writing (Akkermans and Schwartz 2003: 197). It is suggested by some scholars that these developments are made possible with the high agricultural potential of the region, thus indicating that surplus generation was essential (Akkermans and Schwartz 2003: 183).

Research into the Late Chalcolithic period in upper Mesopotamia and southern Anatolia has been widely concerned with the nature and motive of the spread of the Uruk horizon. This cultural phenomenon, representing the earliest forms of urbanization in northern Mesopotamia, is attested by some scholars to intensive contacts with merchant venturers originating from the Uruk state (Rothman and Fuesanta 2003, Sagona and Zimansky 2009: 200). Some argue that the Uruk colonies represent the movement of people, manifest as political "intrusion" (Akkermans and Schwartz 2003: 181). Algaze (1993: 42, 1999, 2001), on the other hand, argues for the "expansion" of the Uruk state across most of Mesopotamia. The author proposes that the alluvial plains of southern Mesopotamia held an advantage in early agricultural practices due to the flow of the Euphrates being more suitable for irrigation technology than the northern sectors of the river (Algaze 1993: 62, 2008: 103), thus leading to an advantage in state economy and surplus generation (Algaze 1993: 67, 2008: 92). Following this rationalization, Algaze also argues that the main hubs of Uruk colonies were founded on rainfed-farming zones, while there are those settlements that display a mixture of local cultural attributes alongside Uruk influence, and these are generally located in dry-farming regions, such as

Tell Brak (Algaze 1993: 98). This line of argument follows that economies based on dry farming would be more prone to collapse with fluctuations in environmental conditions (Ur 2010, see discussion in Akkermans and Schwartz 2003: 197). Urban centers in northern Mesopotamia, often interpreted as outposts of the Uruk centers in the south reflect a downfall 3500-3400 BC (Algaze 2008: 117), coinciding with what is termed the Northern Middle Uruk Period. Evidence for this cycle of urban recession is most evident at Tell Brak in the Khabur Plains of northeastern Syria.

The Khabur region falls into the dry-farming zone (Courty and Weiss 1997) and has a relatively dry climate compared to the alluvial plains of the Euphrates. Tell Brak displays a continued sequence of occupation throughout the 4th millennium BC, with the settlement expanding to at least 65 hectares by the Northern Middle Uruk Period (3800-3400 BC) (Algaze 2008: 118-119). This site, located on a critical point in the Northeastern Syrian trade routes, reaches urban population levels by the late 4th millennium BC, displaying a mix of Uruk and local pottery types in its ceramic assemblages (Schwartz 2007). This is interpreted by Akkermans and Schwartz (2003) to be the result of Uruk being a local center with connections to the Uruk capital, but not a colony thereof, contrasting Algaze's (2008:69) view that such assemblages similar to Brak represent urban settlements of local origin that allow for the residence of "Uruk colonists". Algaze further argues that towards the end of the Uruk period, this urban center is taken over by the southern immigrants (2008:86). However, by the second half of the 4th millennium BC, this site reflects a shrinking in the size of the settlement, a trend similar to those in settlements such as Nineveh.

The Uruk period, as the influence of this city-state is undeniable in the region, represents the initial surge of urbanization in the Near East. Some of the most characteristic attributes of the time period: the establishment of a writing system shared throughout the sphere of influence, the mass-produced ceramic style (beveled rim bowls), and monumental architecture all signal to the centralization of authority. This cultural horizon in northern Syria experiences its demise by the end of the Late Chalcolithic period, with most Uruk sites in the north being abandoned ca. 3100 BC (Akkermans and Schwartz 2003: 209). Much evidence is needed in order to assess the causes behind this demise, however theories postulate on the collapse of agricultural systems that cannot generate enough surplus to support urban populations (Algaze 2008: 121). In addition, the difficulties in correlating the chronology across the region make it difficult to assess contemporaneity when a majority of the discussion relies on the ceramic assemblages of characteristic horizons.

2.2.2 Early Bronze Age

The Early Bronze Age in the Middle Euphrates Valley (ca. 3100-2000 BC: Akkermans and Schwartz 2003: 211) follows the collapse of the Uruk political system. This period coincides with the Predynastic, Old Kingdom, and First Intermediate in Egyptian Chronology and proto-Elamite period in Iran (Kuhrt 1995: 60). In the initial stages of this period in the Euphrates Valley and southeastern Anatolia, there is evidence for a period of rural development and a reduction in central political authority (Sagona and Zimansky 2009: 210, Akkermans and Schwartz 2003: 268). During the initial phase of the Early Bronze Age, there are two distinct cultural traditions in northern Syria, the Ninevite V in the Khabur valley, for example at Tell Leilan and Tell Brak, and in the western part Red-Black Burnished Ware (Akkermans and Schwartz 2003: 211). As many authors note, there were significant changes in the region ca. 2600 BC (Akkermans and Schwartz 2003: 233, Cooper 2006: 15, Sagona and Zimansky 2009: 213, Ur 2010, Weiss 1986:2). The "second urban revolution," termed by Akkermans and Schwartz (2003: 233), signals the secondary surge of urbanization in the region that leads to the rise of city states such as Ebla in western Syria, and spread across Mesopotamia.

In addition to developments in western Syria, the Early Bronze Age in the middle Euphrates valley displays increasing population density (McClellan 1991, Wilkinson 2003: 126). In the Middle Euphrates Valley, and most of Mesopotamia, regional centers and their supporting communities were fortified during this time period with mud-brick enclosures (Kuhrt 1995: 40). Textual records from centers such as Ebla and Leilan provide evidence for warfare and political conflict throughout the region (Kuhrt 1995: 27). There is also increasing evidence for social stratification signaling to the rise of an elite class with the construction of monumental structures such as Tomb 302 at Jerablus Tahtani (Peltenburg *et al.* 1995).

Ebla is a mound site of ca. 60 ha located in Northern Syria that extended its political influence to Carchemish on the western bank of the Euphrates River (Kuhrt 1995: 45). The excavations of this urban center provided invaluable textual evidence on the economy and agricultural structure of the region with the discovery of numerous cuneiform tablets (Milano 1995). Especially valuable for this study are the records concerning the trading of agricultural products (primary and secondary) and textual evidence on environmental change. For instance, it is reported that Ebla engaged in a centralized textile production that based its raw material procurement on pastoralist communities and also centralized metalworking (Milano 1995). Texts from state documents detail the management of the seed stock for wheat and barley, with meticulous records kept on the yields from different field locations, as a way of managing field quality (Milano, 1995).

In the last two decades, the widely held view has been that towards the end of the 3rd millennium BC, ca. 2200 BC, across the region there is an abandonment of urban centers (Akkermans and Schwartz 2003: 282). However, as new data has been made available with the excavations carried out as part of salvage projects along the Euphrates (prior to the construction of Tishreen, Birecik, and Carchemish Dams) there is increasing evidence suggesting that the events that took place through the end of the Early Bronze Age cannot be characterized as a widespread collapse.

Schaeffer (1948) is one of the earliest scholars to suggest an overall destruction and several crises ca. 2300-2100 BC across the Near East. On the basis of evidence from Tell Brak, Tarsus, and Troy, he postulated that the abandonment of urban centers and migrations across the Near East were the result of repeated environmental catastrophes, such as earthquakes (Schaeffer 1948:534-567). Similarly, based mainly on evidence from ancient Egyptian texts, Bell (1971) argued that a great drought across the Near East took place ca. 2200-2000 BC that in Egypt corresponded with the decline of the Old Kingdom. The author states that the region was "afflicted by severe famine and that this was caused primarily by failure of the Nile floods" on which successful farming seasons depended (Bell 1971:24). These views on the Early Bronze Age collapse were later supported by scholars such as Weiss *et al.* (1993) who suggested that the phenomenon was visible and prevalent in the Khabur region of northern Syria, and was likely caused by climatic change (Courty and Weiss 1997). With an increasing amount of evidence, this topic is highly debated in the Middle Euphrates valley (cf. volume on this topic Marro and Kuzucuoglu 2007). It is evident that there are global environmental changes taking place at this time (Dalfes *et al.* 1997, Bond *et al.* 1997), and these issues will be discussed further in this chapter. Socio-cultural evidence provides a mixed record for the time period, while certain sites such as Jerablus Tahtani, Tell Qara Quzak, and Tell Shiyukh Tahtani in the Middle Euphrates Valley are abandoned ca 2300-2100 BC, other sites such as Horum Höyük and Carchemish remain continuously occupied throughout this time period and even expand in population size (Schwartz 2007).

2.3 Climatic/Environmental Setting

Interpretations of the cultural ecology of prehistoric Middle Euphrates Valley differ markedly in archaeological discussions. While some authors argue for a polarized environment with access to natural resources defining socio-cultural events, others argue for a complexity of environmental conditions and consequent human responses. For instance, as an example of the former, Algaze argues that the alluvial lowlands of the region were lacking in several crucial resources that were required for a sustainable existence, which would have been a prerequisite for the development of intricate socio-political networks in the region (Algaze 1993:2). Today, northern Syria is dominated by low-lying limestone plateaus covered by steppe, while in southeastern Turkey these plateaus rise slightly closer to the Taurus range that runs East-West (Kuzucuoğlu 2007). In the Euphrates River valley, annual precipitation is high during the early winter and spring, with arid summer terms increasing in the southern direction (Kuzucuoğlu 2007, Cooper 2006: 28). In the middle Euphrates valley, present day agricultural production adheres to the seasonality of precipitation (app. 300-500 mm/annual) and flooding, with wheat and barley as the most important crops in dry-farming (Kuzucuoğlu 2007).

The Euphrates River runs south through the Taurus Mountains into the northern Syrian steppes. Towards the southeast, the river is fed from the branches of the Balikh and Khabur. As the Euphrates takes a turn near present day Baghdad, the low riding slopes of the southern plains cause a reduction in the power of the stream flow resulting in high alluvial deposits (Wilkinson 2007). In the northern sector, however, the Euphrates flows within narrow floodplains. In these areas the Euphrates flows at high energy, beneath terrace levels, making irrigation difficult (Wilkinson 2007). Much of the success of irrigation agriculture depends on the right amounts of flooding: too high or too low floods can either threaten the settlement or ruin the annual crop (Roberts 1998: 173). Due to its location in the sub-tropical high-pressure belt, the region is arid, receiving most amount of rainfall in the winter (Wilkinson 2007). In most of the Upper/Middle Euphrates Valley down to the present day Turkey-Syria border, the annual rainfall is reliable enough to support dry farming (greater than 300 mm/year) (Ur 2010). To the south, there are extensive steppes surrounding the river valley with insufficient amounts of annual rainfall to support dry farming (Cooper 2006: 28).

Climatic and environmental proxy data (Hole 1994, Algaze 2005) indicate considerably wetter climates during the 5th and early 4th millennium BC. After this period, geoarchaeological and palynological studies suggest that there was a general trend (later 4th millennium and early 3rd millennium) towards increasing aridity, followed by an abrupt climate change event ca. 2200 BC (Algaze 2005, Peltenburg 2007a, Kuzucuoğlu

2007). Algaze (2005) suggests that during the earlier part of the Early Bronze Age (ca. 3rd mil. BC), right before the abrupt aridification event, a period of optimum precipitation, especially during the summers, would have benefited pastoralism and cereal farming leading to an increased potential for agropastoral production. In general, as discussed by Kuzucuoğlu (2007) there are two main types of environmental/climatic data indicators, one that is exclusively indicative of climate (i.e. sediment cores from lake bottoms, tree-ring data, and isotopic evidence of carbon and oxygen) and a second that is indicative of the general trends of the environment (i.e. geoarchaeological studies of sediments, archaeobotanical and archaeozoological assemblages).

According to oxygen isotopic evidence from the Greenland ice core, there are various peaks in climate change throughout the 3rd millennium BC, corresponding to droughts in the Near East in 2800, 2650, 2450, 2350, and 2050 (Shackleton *et al.* 2004). It is noted that these peaks have varying degrees of intensity, and can be challenging to correlate chronologically. However, further evidence of global climatic events come from cores in the North Atlantic ocean, representing cycles of climate change with peaks roughly every 1500 years (Bond *et al.* 1997). According to the North Atlantic records, there are two peaks one at 3900-3800 BC and another at 2200-2050 BC, corresponding to droughts in the Near East (Bond *et al.* 1997).

According to isotopic sequences from the Soreq Cave in Israel the general humidity levels in the Near East start to drop at ca. 5300 BC, continue decreasing until 2000 BC (Bar-Matthews *et al.* 1997, 2003). It is suggested that around 2250-2150 BC, annual rainfall could have dropped by approximately 300 mm in total (Bar-Matthews *et al.* 1997). Kuzucuoğlu concludes that this cumulative drop in annual rainfall would have had a noticeable impact on the agricultural systems in the Middle Euphrates Valley (2007:468).

Sedimentary and geomorphological sequences from the Dead Sea region in the Near East provide evidence for a rapid fall in water levels at ca. 2500 BC (Frumkin *et al.* 2004). Also, Migowski *et al.* (2005) report a similar trend as demonstrated by sedimentary analyses from the region. Looking at the trends for change in the geomorphology over the course of the Holocene, it is possible to loosely correlate these with isotopic and pollen evidence.

Multi-proxy data from Lake Van (pollen, charcoal, oxygen isotope, and magnesium/calcium ratios) indicate favorable climatic conditions in the region between 6200-4000 varve years BP (≈ 5th-4th mil. BC) with increasing aridity ca. 3800 varve years BP (≈ 3000 BC). The slightly later dates of the aridification are due to the fact that Lake Van, located in central Anatolia is further north than the other climate indicators discussed, and so could be reflecting a slightly later symptom of a global aridification (Wick *et al.* 2003).

Geoarchaeological studies indicate (Courty 1994, Courty and Weiss 1997) that in the Khabur region there is a strong indication for abrupt climate change ca. 2200-1900 BC. Based on soil proxy data from the Khabur plains, Courty and Weiss (1997:117) argue that there was a widespread environmental demise during this time period, coinciding with the settlement hiatus at Tell Leilan. After this period, the alluvial sediment record shows a less disturbed climatic pattern, which also coincides with the re-settlement of the region (Courty and Weiss 1997). Furthermore, Courty (1994:55) presents evidence on the sedimentological record of phases prior to this sudden drying phase and argues that even though there is evidence for gradual deterioration of the climatic conditions ca. 3400-2200 BC (spanning most of the Late Chalcolithic and the Early Bronze Age), the abrupt nature of the drying phase ca. 2200 BC would have been pronounced.

From an evaluation of climatic/environmental proxy data, it is apparent that there is an overall trend in the region towards aridity throughout the 3rd millennium BC, with an abrupt drying phase ca. 2200 BC. This situation would have put the dry-farming settlements in the Middle Euphrates Valley under considerable risk of crop failure.

Date	Euphrates River flow (Kuzucuoğlu 2007)	Soreq Cave (Bar-Matthews *et al.* 1997, 2003) Dead Sea (Frumkin *et al.* 2004)	Global (Bond *et al.* 1997)	Lake Van (Wick *et al.* 2003)
4000 BC	Stable channel	Wetter than today		Still humid
3800 BC			Dry peak	
3600 BC				
3400 BC		Drier	Short drought	
3200 BC				
3000 BC	Extreme floods			Decreasing rainfall
2800 BC			Short drought	
2600 BC	Increasing sediment load	Moister		
2400 BC				Drought
2200 BC	Extreme floods	Drought	Dry peak	Dry peak
2000 BC				

Table 2.1 Summary of paleoenvironmental proxy datasets discussed in text.

2.4 Agriculture/Subsistence

The onset of urbanism in the region, ca. 4000 BC as discussed earlier with the Uruk influence across Mesopotamia, brought about a change in agricultural practices that is reflected in botanical assemblages with increasing proportions of productive crops (Rivera-Núñez *et al.* 1999). There are greater proportions of barley in comparison with emmer wheat, and a concurrent decrease in the ubiquity of flax in assemblages of charred plant remains found on sites (van Zeist 1999:370). In samples of botanical macro-remains throughout the Middle Euphrates valley barley is the dominant crop, and faunal analyses indicate that pastoralism played a significant role in the early agricultural economy of the region (Dönmez 2006, Deckers and Riehl 2007, Riehl 2009, Nesbitt 1997). On this note, McCorriston (1997: 519) argues that the decreasing abundances of flax found on sites is indicative at this time of a greater emphasis on wool for textiles, in addition to making more cultivatable land available for cereal crops. It is noted that at the turn of the 3rd century, the frequency of flax across the region decreases while evidence for wool textile working increases (especially textual records from states such as Ebla and Ur). Eventually, the use of wool for textile production becomes widespread replacing linen made from flax. This situation coincides with the faunal record, as sheep and goat almost always dominate the assemblages of Upper Mesopotamia during the Early Bronze Age (McCorriston and Wiesberg 2002, Zeder 1994). It is noted by Gelb (1986) that sheep herding was mentioned in Ebla texts frequently and that the major export products from this state to the southern regions were wool and textiles in exchange for grains. In terms of animal husbandry textual evidence in the later part of the 3rd millennium BC indicates an increased focus on sheep herding, however further faunal analyses are necessary to evaluate the extent of these trends.

The agricultural economy during the later phases of settlement in northern Syria and the Euphrates valleys coincides with the second surge of urbanization during the Early Bronze Age and reflects a greater emphasis on barley alongside increasing pastoralism (McCorriston and Weisberg 2002). As more paleoenvironmental research is undertaken it has become clear that the ecofactual data reflect considerable variability across the region. For instance, archaeobotanical analyses on macro-remains from Hassek Höyük show a greater emphasis in barley cultivation as opposed to wheat; however, during the Early Bronze Age there is a greater emphasis on free-threshing wheat, while in the Middle Bronze Age emmer wheat is more prevalent (Deckers and Riehl 2007). It is possible that free-threshing wheat was grown in preference due to the ease of processing this crop over emmer wheat, and a later switch to emmer could be due to fact that it is more drought tolerant than free-threshing wheat. In northern Syrian sites such as Tell Leilan (Wetterstrom 2003) and Tell Brak (Hald and Charles 2008), hulled wheat seems to be as important as barley.

Evidence of olive cultivation along the Euphrates comes from Horum Höyük, Tilbeşar and Emar with increasing abundances and frequencies of olive wood charcoal and olive stones during the Early Bronze Age (Deckers and Riehl 2007). Further south there is evidence of olive wood, suggesting olive cultivation at Tell Mozan dating to the Middle Bronze Age (Deckers and Riehl 2007). At the end of the 3rd millennium BC there is a region wide decline in the amount of oak park woodland (Deckers 2005). Deforestation is prevalent in the Near East throughout this period of urban settlement and is explained by the over exploitation of wood for fuel (Roberts 1998: 201). It is argued by some authors that the appearance in Early Bronze Age archaeobotanical assemblages of burnt dung fragments and weedy taxa commonly consumed by livestock represents the use of dung as fuel as a strategy to provide an alternative fuel source to firewood (Schwartz and Miller 2007).

2.5 Jerablus Tahtani

Jerablus Tahtani, located on the right bank of the Euphrates River in Northern Syria, is first mentioned in archaeological literature by Woolley in his report of the excavations at Carchemish (referred to as Tell Alawiyeh, Woolley 1921:38). The site is located 5 km to the south of the Early Bronze Age urban center, Carchemish. Jerablus Tahtani is a mound site of ca. 4 hectares, rising to 16 meters on the western edge of the floodplain (Peltenburg *et al.* 2000). In the 1970s and the 1980s survey work established Jerablus Tahtani as a Late Uruk/Early Bronze Age settlement. The first systematic excavations site of were carried out under the direction of Dr. Edgar Peltenburg between 1992 and 1999 (University of Edinburgh) as part of the Tishreen International Rescue Programme before the flooding of the region due to the construction of the dam. As a result of excavations and analyses carried out in the following years, a five period sequence of occupation was devised that spans from the Late Chalcolithic to the Islamic period, with site abandonment at the end of the Bronze Age and the subsequent resettlement during the Iron Age (Peltenburg *et al.* 1995, 1997).

In terms of its location Jerablus Tahtani is quite different from most other sites in the region, situated on a 5 meter high terrace on the edge of the present day river (Peltenburg *et al.* 1995). Survey work indicates that most other sites in the region are either further away from the riverbank or on higher terraces compared to Jerablus Tahtani (Wilkinson *et al.* 2006, Peltenburg 2007a). The exposed location of the site resulted in the erosion of the eastern side of the tell (Peltenburg *et al.* 1995). In addition, there is evidence of several layers of flood deposits in occupation levels of the low-lying tell

(Peltenburg 2007a). This feature of Jerablus Tahtani is shared by only a few other sites along the Middle Euphrates Valley (Peltenburg 2007b).

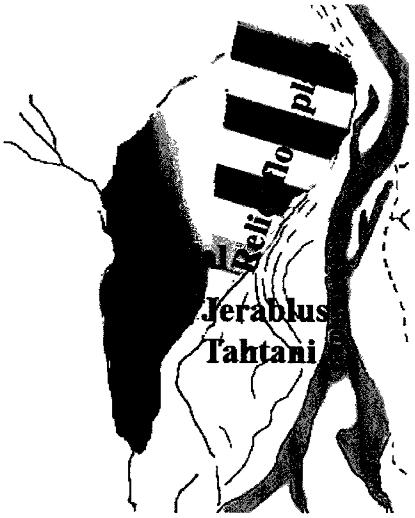

Figure 2.2 Map of alluvial fan around Jerablus Tahtani, modified after Wilkinson 2007:33.

Jerablus Tahtani is also one of the few settlements along the Euphrates where portions of the early floodplain valley floor are preserved (Wilkinson 2007) (Figure 2. 2). This section of the relict floodplain extending over 8 km to the north would have been cultivated land during the 3rd millennium BC (Wilkinson 2007:31).

The construction of three major dams on the Euphrates River in the last decade resulted in the sudden increase of archaeological research in the Euphrates Valley. The rescue excavations of the Carchemish and Birecik Dams in southeastern Turkey and the Tishreen Dam in northern Syria have provided a wealth of information in this key region (Wilkinson 2007). As Peltenburg (2007b) mentions, a majority of the sites excavated and reported through survey belong to the Early Bronze Age. In contrast, little is known about the important transition between the Late Chalcolithic to the Early Bronze Age due to the low number of sites with continuous stratigraphy during these time periods. Jerablus Tahtani not only provides this crucial link but also with its close proximity to major polities in the region (Carchemish, Ebla), provides evidence for regional socio-political change (Peltenburg 2007a).

Various artifacts reported at the site indicate the importance of the site in the region, especially in terms of trading in the north-south and east-west sectors of the Middle Euphrates Valley. McCarthy (2007) in analyzing seal impression styles at Jerablus concludes that the site displays a variety of styles originating from across the Near East. For instance, there are visible signs of influence in glyptic styles from northern sites such as Tarsus, Gre Virike, and from Uruk sites in the south, in addition to regional styles from the west in Ebla and from the east of the Euphrates such as Tell Brak and Tell Leilan. McCarthy (2007) concludes that this signals to the hybridization of cultural styles at Jerablus, a situation that is contrasted in the city-states of southern Mesopotamia where sites tend to display uniform styles in ceramic seals.

The chronological sequencing at Jerablus Tahtani was carried out using the regional sequencing compiled by Jamieson (1993) based on ceramic sequences obtained from the entire region (Peltenburg 1999a). Accordingly, Period 1 at Jerablus Tahtani coincides with the Late Chalcolithic/Uruk phase dating to the mid-4th millennium BC. It is noted that most of the evidence from this time period belongs to the Uruk phase, with a strong dominance of Uruk style pottery, however an earlier level of local Late Chalcolithic has been identified, and the sequencing has been altered to reflect this, 1A: Local Late Chalcolithic and, 1B: Uruk levels (Peltenburg *et al.* 2000). Period 2 at Jerablus Tahtani designates the Early Bronze Age sequence, with 2A representing the earlier Early Bronze Age and 2B representing the latter half, characterized at the site by the construction of the fortification wall (Peltenburg *et al.* 2000). At the end of the 2B period, the site is abandoned for more than a millennium, and re-settled in the Iron Age (Peltenburg *et al.* 1997).

Period	Regional Chronology
1A	Late Chalcolithic
1B	
2A	Early Bronze Age
2B	
3	Iron Age
4	Roman
5	Islamic

Table 2.2 Summary of site chronology at Jerablus

The size of the settlement is unknown during Period 1 at Jerablus Tahtani due to flooding eroding the east bank of the tell dating to this time period (Peltenburg 1999a). It is noted that preliminary analyses carried out on macro-botanical remains from this period suggest an emphasis on barley (Peltenburg *et al.* 1997) and furthermore "relatively pure sample of barley from a secured context is consistent with cleaned crop storage" (Peltenburg 1999a: 99).

Period 2 provides a more detailed evidence of occupation, and in fact most of the surviving evidence at the site dates to the Early Bronze Age (Peltenburg 1999a). Period 2A represents the earlier part of the Early Bronze Age, corresponding to the period prior to the fortification construction. There are several finds dating to this time period that suggest increasing socio-political complexity (i.e. cylinder seals indicative of centralized trading) and an increase in settlement density mostly in Area III of the site (Peltenburg

2007a). During Period 2B substantial effort is put into the construction of the fortification wall (Peltenburg *et al.* 1997). As mentioned earlier, this coincides with the regional trend at settlements in the Middle Euphrates valley for the construction of fortification walls ca. 2600 BC. There is evidence from this occupation phase for increasing administrative control over production (i.e. textile working) and a rise of elite class (Peltenburg 1999b). Evidence gathered from Tomb 302 dating to this stratum reveals status differentiation with the construction of a burial mound that is elevated higher than the rest of the settlement (Peltenburg 2007a).

The fortification walls that were built during the Early Bronze Age were excavated in Area I (see Figure 2.3), and extends about 32 m (Peltenburg et al. 2000). Within this enclosure, the Early Bronze Age settlement was organized in a north-south orientation. The Local Late Chalcolithic occupation sequence was preserved in Area III, followed by an Early Bronze Age sequence. It is mentioned that in this area the end of the Chalcolithic period is marked by a thick layer of ashy deposits suggesting a widespread destruction layer. However, the extent of such an event is not clear for the rest of the site due to erosion by periodic Euphrates river floods. In fact, in Area III and IV, where the Late Chalcolithic deposits are preserved due to their protected locations on the tell away from the riverbank, there seems to be a dramatic change in building construction, shifting from mud-brick to stone walls (Peltenburg *et a*l. 2000). It is also noted by Peltenburg (2007a) that quern stones found in building 1000, from Area IV show a shift during the Early Bronze Age, where the earlier part of the sequence displays much lower numbers of querns and grinding stones for cereal processing than the later phases of the sequence within this context. It is suggested that this area represents a centralized production area with evidence for food processing, along with the appearance of metalworking implements.

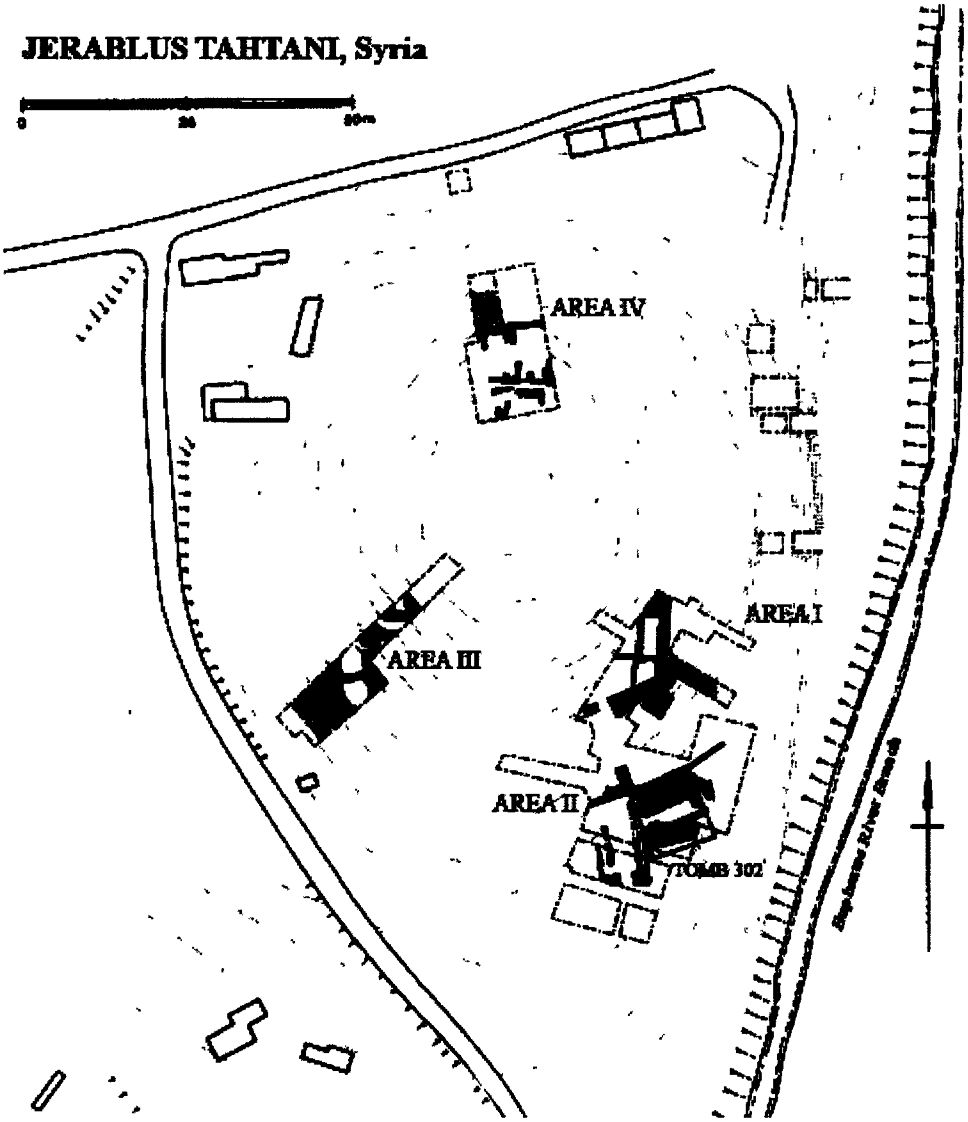

Figure 2.3 Map of excavated areas at Jerablus Tahtani, after Peltenburg *et al.* 2000: 54.

Preliminary analyses on botanical remains from Jerablus suggest that barley could have a more important role in the crop assemblage (Murray 1995, 1996). In addition, there are storage contexts for cleaned barley grain, and cleaned lentil. The samples taken from the elite tomb complex T 302 have been sorted and analyzed by Colledge and Stevens, and the resulting unpublished report indicates clear high percentages of cereal crops, hulled wheat and hulled barley, with smaller amounts of pulses and wild grasses (Colledge and Stevens, forthcoming). In analyses of wood charcoal fragments from Jerablus, Populus/Salix dominate the charcoal assemblages, interpreted as an indication for the presence of a prominent riverine forest throughout the Early Bronze Age in the surrounding area(Deckers and Pessin 2010).

In order to assess the nature of early agriculture in the Euphrates Valley, and in the Near East in general, much work needs to be done. However, ecofactual evidence from Jerablus Tahtani can provide valuable information on the shifts in agricultural practices in relation to the formation of elite groups in smaller settlements. As noted in Colledge (2003) archaeobotanical assemblages can be indicative of processing preferences, cropping practices, location of agricultural fields, and pastoral strategies, and the botanical analyses at Jerablus Tahtani will allow for a more thorough evaluation of the agricultural economy at a socially dynamic time period such as the Late Chalcolithic and Early Bronze Age. With regards to arguments on the rise of the Uruk state and its spread the site holds great promise to explain how this influence spread out to smaller centers along the Euphrates. Due to the fact that there is evidence of a locally based Late Chalcolithic, macro-botanical evidence from this little known time period will shed light on the agricultural economy of the site. Furthermore, since most theories on Uruk expansion/intrusion argue for the receptiveness of smaller centers, it will be possible to evaluate these claims with the evidence available from Jerablus, especially in comparison to bigger urban centers such as Tell Brak. Additionally, since the site displays evidence of abandonment at the end of the Early Bronze Age, it will be possible to evaluate archaeobotanical evidence with regards to changing ecological conditions.

In the next chapter, a review will be provided of possible taphonomic factors influencing the preservation of botanical remains in archaeological sites.

Chapter 3: Formation Processes of the Archaeobotanical Record

3.1 Introduction

This chapter outlines the processes that determine the composition of archaeobotanical assemblages. The discussion here is limited to the factors influencing the preservation of botanical material, specifically macro-botanical remains, with emphasis placed on carbonization, deposition, and any disturbance to contexts (pre- or post-deposition). In this regard, since fire plays an important role in the preservation of plant material, there is discussion pertaining to how plant material comes into contact with fire, and how this has an effect on the morphology of charred plant material. In order to address research questions relating to the diet and subsistence strategies of prehistoric populations, and to reconstruct ecological conditions through plant taxa it is necessary to present the limitations of the representativeness of archaeobotanical assemblages.

In essence, understanding the pre-depositional, depositional, and post-depositional processes involved in the formation of the archaeobotanical record is very important in our interpretations of botanical data. A better understanding of the socio-cultural processes, natural processes, and the recovery techniques that influence the taxonomic composition of archaeobotanical samples allows a more comprehensive analysis and interpretation of people-plant interactions at a given site.

Studies on depositional processes in archaeology have been lead by processual influences. In particular, Clarke (1973) outlines five levels of processes involved in the formation and production of archaeological data, which has been very influential in archaeobotanical studies (see for instance Wright 1998, Fuller and Weber 2005). Clarke (1973) also outlines five separate levels of "theory" that help us deliver the archaeological remains into an interpretative scheme: "pre-depositional and depositional", "post depositional", "retrieval", and "analytical" and "interpretive" (Clarke 1973:16-17). Pre-depositional and depositional processes relate to the patterns that result in the deposition of botanical material in various contexts. Post-depositional processes relate to the disturbances to the initial context and the affects of a secondary set of actions on the composition of the samples. The remaining three categories pertain to the direct involvement of the archaeologist, whereby the retrieval process relates to methods of recovery for plant remains, the analytical process relates to the methods of sorting and quantification, and the interpretive process relates to the inference made about archaeobotanical data with respect to behavioural or other socio-cultural patterns. These processes influence the formation of the archaeological record, and close attention paid to the excavation, recovery and analysis techniques can reduce the "bias in the patterning of the archaeobotanical data" making interpretations of patterning in the data more sound (Hastorf and Popper 1988: 6).

In archaeobotanical macroremain assemblages, a majority of the taxa that are preserved represent plants that have come into contact with fire, either intentionally or accidentally, therefore plant macroremains do not reflect a random distribution of all the plants in the environment, rather they reflect a series of depositional events that lead to the plant remain to arrive at the site, be exposed to fire, reach a state of complete charring, and be incorporated into the archaeological record (Schiffer 1987: 181). Furthermore, after these steps, the plant remains have to go through another selective process prior to analysis in the lab, field recovery, as will be discussed in greater detail in Chapter 4.

3.2 Formation Processes

There are two possible ways plant remains travel to a settlement: they may be collected, either intentionally (in the case of crops), or unintentionally (in the case of weeds of crops); or they are not collected but travel to the site in an accidental manner (windblown, carried by insects, etc.) After arrival at the site, if the use or discard of the plant involves fire exposure, it may become charred (incomplete combustion) and therefore can be preserved (Evans and O'Connor 1999:137-139). A schematic view of these pre-depositional, depositional, and post-depositional processes can be seen in Figure 3.1.

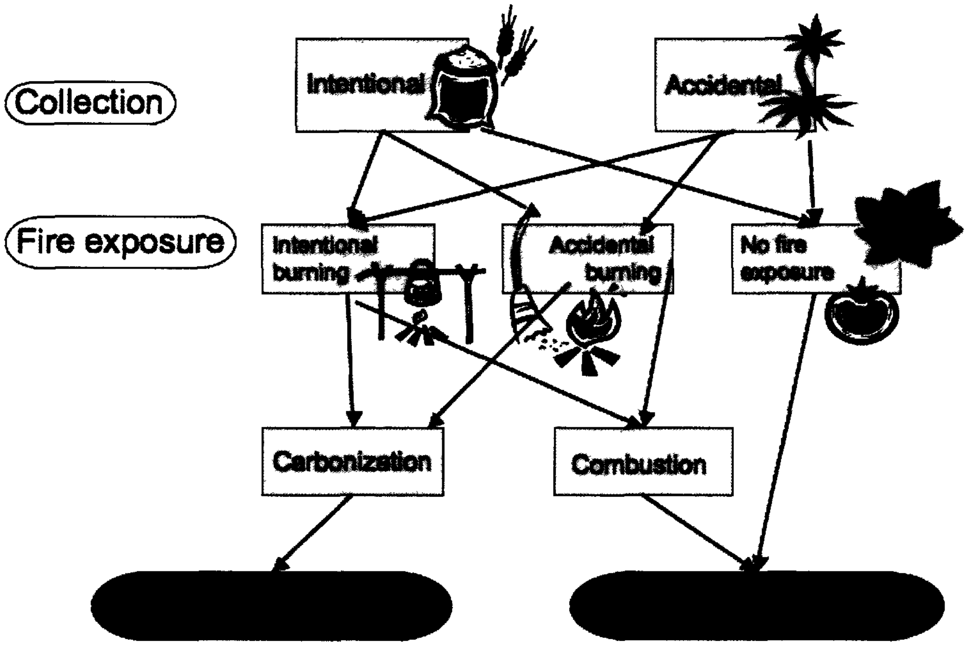

Figure 3.1 Schematic summary of taphonomic processes

Due to the high likelihood that a majority of the plant species represented in botanical assemblages will be sourced from intentional collection (crops and weeds intended for human use), the main body of this chapter will be dedicated to explaining the various processes involved in the collection and discard of these types of remains. Amongst these, remains of whole or fragmented seeds, wood charcoal, fruit stones, nuts, and tubers form the majority of the identifiable taxa (Hastorf and Popper 1988: 5, Pearsall 2000: 99, Colledge 2001: 18). Certain taxa, due to their chemical compositions can preserve without exposure to fire, such as the members of the Boraginaceae family (Miller 1991). It should also be noted that in rare circumstances, plant macroremains can preserve through desiccation (i.e. in extremely arid conditions, Evans and O'Connor: 138, Popper 1988). Taxa that are not usually exposed to fire such as leafy vegetables most likely will not be represented in archaeobotanical assemblages despite the fact that they might be abundant around settlements and grown as crops (Evans and O'Connor 1999: 139). In addition, certain parts of plants such as dense nutshells and seeds with high cellulose contents are better preserved than fleshy fruits and tubers with high sugar and starch contents (Popper 1988).

3.2.1 Carbonization

A majority of the macro-botanical remains are preserved as a result of exposure to fire (Evans and O'Connor 1999: 138). Charring is a state in which plant material has gone through partial combustion to convert its organic components to carbon, also referred to as carbonization (Popper 1988: 54). At this stage, the temperature and the duration of exposure to fire determine how well (or otherwise) the plant taxon is preserved in recognizable form rather than being completely burnt (or even reduced to ash), thus rendered unidentifiable (Gustafsson 2000, Boardman and Jones 1990). Most often, carbonization alters the morphology of the plant remains leading to difficulties in identification (Hastorf and Popper 1988:8).

Generally, the more durable parts of plants survive the charring process, for instance seeds, stones, or nutshell. There have been various charring experiments carried out in order to investigate whether different parts of plants and different seeds survive the charring process. Boardman and Jones (1990) report that, cereal grains are more likely to survive charring than cereal chaff elements. While certain fragments of chaff survive, these usually are the more robust parts such as the glume bases and the rachis (see Figure 3.2).

Van der Veen (2007: 977) notes that the likelihood of preservation of taxa varies in clusters of taxa groups of similar qualities that tend to respond similarly during charring. For instance, cereals grains tend to preserve better than cereal chaff. Pulses, wild taxa and taxa with high oil contents are often poorly preserved. There is also a tendency for cereal grains to become deformed at high temperatures (higher than 250°C), whereas grape seeds tend to carbonize at 450°C, and pulses at 450°C (Guarino and Sciarrillo 2004, Margaritis and Jones 2006). It is highly likely that a range of taxa and a variety of plant parts will be exposed to the same fire (e.g. hearth, oven) resulting in the differential preservation of different elements due to their differential requirements for charring temperatures leading to a partial and very limited representation of the entire suite of plants used at a site (Wright 1998:28).

It is debated as to the degree to which the compositions of archaeobotanical assemblages represent the overall plant usage at a site, or even in a single context. It is reported that seeds that have higher oil contents (such as flax) are likely to become unidentifiable as a result of the high flammability of the oils and the subsequent rupturing of the testa (Gustafsson 2000, Wright 1998: 27). To this end, the experiments carried out by Gustafsson (2000) and Boardman and Jones (1990), among many, provide some useful insights. Through various outdoor charring experiments, Gustafsson concludes that under the same charring conditions most cereal grains would have similar chances of preservation (2000: 69). Even though there remains more work to be done on this aspect of the preservation processes, these studies provide insights into the proportional representativity of archaeobotanical assemblages, especially concerning comparisons of cereal crops (i.e. wheat and barley).

In general, the processes the plant material goes through before carbonization (pre-depositional processes) and during carbonization (depositional) are such that the end result, in terms of the charred plant remains that are recovered, represents only a partial view of the actual consumption or use patterns of humans. Post-depositional processes, such as burrowing by animals, and shifting of fire hearth contents by humans limit the extent of botanical data. For instance, Peña-Chocarro et al. (2009) provide ethnographic examples of fire hearth management where the contents of the fire are sifted through after initial use and the bigger chunks of wood are saved for later use while the ashy waste is discarded.

3.2.2 Crops: Harvest and Processing

Several authors note that, as crops become more important in subsistence, especially in the Near East and Europe, most botanical assemblages reflect an abundance of crop species, accompanied by a higher representation of weeds of agriculture (Fuller and Weber 2005, Minnis 1981, Hillman 1973, 1981, Dennell 1976). As mentioned earlier, one of the ways in which plant material is deposited at a site is through accidental gathering, and with harvesting of crops in the field the inclusion of weeds of agricultural fields in archaeobotanical assemblages is quite common. The interpretation of ecological data through weeds can provide to be extremely useful, especially in evaluating environmental conditions under which the crop species were growing. These wild taxa, having adapted to conditions in agricultural fields, tend to reflect the methods of harvesting (i.e. what types of weeds survive sickle harvesting vs. plucking), timing of sowing or timing of harvesting (i.e. what are the seasons of flowering for the weed taxa to be able to survive field conditions and complete the flowering cycle) (Bogaard 2004:8). Therefore, we are able to analyze certain ecological features of the agricultural fields by looking at the weeds that accompany the crops: for instance the levels of rainfall, sowing season, and the presence or absence of manuring or irrigation.

Ethnographic evidence of traditional harvesting and processing for cereal grains from the Near East provides important comparative data that enable the interpretation of archaeobotanical assemblages of crops and weed taxa that reflect the products and bi-products of crop processing (Hillman 1984, 1985). Some farmers harvest cereal crops by hand (called the 'plucking' method), which reduces the amount of straw and weeds harvested along with the crops and the cost of increased labour input. Conversely, by sickle harvesting or uprooting an abundance of field weeds and straw is gathered along with the cereal heads (Jones 1996), however, this method is less labour intensive. There are also various other methods of cereal harvesting that involve the use of different kinds of sickle blades that result in different lengths of desired straw length (Peña-Chocarro et al. 2009, Zapata-Peña et al. 2003). An important factor in the choice of harvesting method lies in the potential use of the harvesting bi-products following processing. For instance, (Peña-Chocarro et al. 2009) indicate that in the mountainous settlements of Morocco, wheat harvesting is done with special care given to the length of the straw due to the valued use for this bi-product as roof thatching. As will be discussed later, different types of harvesting method can have certain implications on the use of crop processing debris for fodder. In addition, harvesting technique can have environmental motivators, for instance hard, unyielding soils will not allow for harvesting by uprooting, and it might be more advantageous to harvest thick cereal stands with sickles (Bohrer 1972).

After harvesting, crops are often processed to be stored as the storage of unprocessed crops right after harvest is rare (Jones 1998). It is noted that in hulled cereal grain processing large quantities of glumes, glume bases, and rachis segments are discarded through all stages (see Figure 3.2 on hulled wheat anatomy) (Hillman 1984).

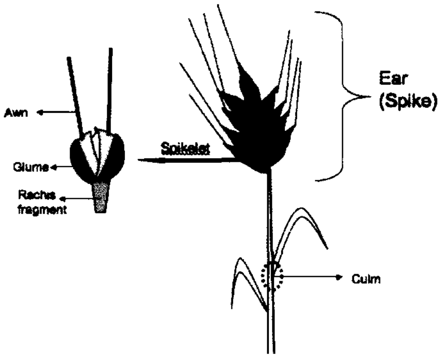

Figure 3.2 Anatomy of hulled wheat.

The sequence and the processing of crop waste depend on preference and also on the type of crop and what might be necessary to render it palatable prior to consumption. Depending on the qualities of the cereal grain, extra steps might be necessary, however, the basic steps involved in cereal crop processing are threshing, winnowing, and sieving. Hulled cereals (einkorn wheat, emmer wheat, and hulled barley) require extra steps to remove the grain from the hull, such as pounding, and parching, thus the cultivation and processing of these grains can be more time consuming and intensive if more human labour is used, extensive if more animal labour is used. On the other hand, free-threshing cereals separate from the hull with ease, so crop processing after harvest is much less labour intensive.

The initial step that harvested cereals go through is threshing: by beating or pounding the edible seeds, spikelets are separated from the rest of the plant. After this winnowing and coarse sieving are used to separate the straw and the bulk of the plant from the edible parts. Hulled cereal grains (such as hulled barley, einkorn and emmer wheat) require dehusking as a further step. Dehusking is usually carried out by pounding the cereal heads to separate the husk (e.g., the glumes) of the cereal grain. At this stage, further sieving might be carried out, depending on preferences for storage. The archaeobotanical signatures of each of the products and bi-products would be different and can have some indications on the amount of labour involved in subsistence (Hillman 1981, 1984, 1985).

Hillman (1981, 1984, and 1985) proposed a model of food processing based on the composition of archaeobotanical samples, arguing that a higher incidence and proportion of cereal chaff elements compared to whole grains (especially culm nodes and internodes from the straw) would indicate that cereal crop production would have taken place on site. On the contrary, if the cereal grain elements outnumber the chaff elements, Hillman interpreted this as an indication that cereal production takes place elsewhere and is imported into the site. Critics of models on crop production location inferred from chaff/grain ratios (van der Veen 1999, van der Veen and Jones 2006) have pointed out that, as discussed above, cereal grains and chaff elements have different likelihoods of preservation once exposed to fire. In addition, the use of straw and other waste products on site for bedding, construction elements in roof thatching, or in mud brick could account for their high occurrence in assemblages. Furthermore, different harvesting techniques would result in different archaeobotanical signatures, where harvests close to the grain would result in shorter straw brought onto the site.

As the crop goes through threshing, winnowing and further sieving, it is separated from weed taxa that might have accompanied the crop in the fields. Therefore, depending on whether crop processing is carried out on site, or closer to the crop fields, the likelihood of weed taxa preservation in the archaeobotanical record is reduced immensely. Dennell (1972, 1976) notes through grain cleaning weed seeds and smaller grains of the crop are separated while winnowing removes the chaff, rachis fragments and lighter weeds.

After the initial step of threshing and winnowing, some societies store hulled wheat (such as einkorn and emmer) in whole cereal ears, and further processing is carried out just prior to consumption (Jones 1996). Certain crops such as barley might be stored in the hull, or might be stored after they have been processed, the same being true for wheat (e.g., *bulgur*, which is stored after the wheat has been parboiled) (Hillman 1984). Parching, a method used to loosen the chaff of hulled grains by short exposure to fire, tend to affect the likelihood of preservation of those species in the archaeobotanical record. Therefore, a higher representation of glume wheats compared to free-threshing wheat, the latter of which do not require parching to separate grains from the hull, would be expected (Wright 1998:40).

In most cases, the waste of crop processing is either stored for fuel, fodder, bedding etc. (Jones 1998). In fact, it is often the case that grains cultivated for fodder end up going through a process of sorting in much the same way as grains cultivated for human consumption (Charles 1998, Anderson and Ertug-Yaras 1998). Van der Veen (1996) also notes that, in conjunction with textual evidence, the high occurrence of cereal chaff and straw at the Roman settlement of Mons Claudianus indicates that this by-product of cereal processing was in fact traded between sites due to its high economic value.

There are various techniques involved in food processing ranging from grinding grains into flour or grits, malting, fermenting, etc. however the archaeobotanical signatures of these are difficult to asses on a macroremain level (Hastorf and Popper 1988:7). Valamoti (2011) in a study of traditional cereal grain processing and subsequent charring experiments, notes that there could be an archaeobotanical signature for the preparation of certain items such as *bulgur* and *tarhana*, both prepared throughout the Near East and Mediterranean. *Bulgur* is made by parboiling wheat (sometimes barley) and grinding after the grains have sun dried. This preparation, as noted by Valamoti (2011) allows for the storage of quick cooking grains, so would have been preferable for daily consumption. In addition, the preparation of *tarhana*, a soup base made from bulgur and fermented milk or yogurt (for the lactic acid contents) allows for a superior protection of the grain from infestation and spoilage (Valamoti 2011). The author postulates that concentrations of ground cereal finds from the site of Mesimeriani

Toumba (Early Bronze Age, northern Greece) reflect storage of processed grains, either pounded or ground. Further processing, for instance parboiling, treatment with lactic acid can be determined with micromorphological studies (Valamoti 2011), and much work remains to be done before food preparation technology can be inferred from macroremains.

3.2.3 Inclusions in Dung and the Question of Fodder

Quite often crops used for fodder for herbivorous livestock at archaeological sites are deposited in various contexts either discarded as waste or through the use of dung for fuel. Several taxa survive the gut flora of domesticated livestock, and when dung is used as fuel in fires these seeds carbonize, adding to the range of plant taxa that preserve in the archaeobotanical record (Anderson and Ertug-Yaras 1998). As Jones (1998, 1992) indicates, it can be difficult to have a clear-cut idea of which crops are used for fodder and which for food. For instance, there is ethnographic evidence that in much the same way, fodder goes through processing where the grains are separated and stored for animal consumption throughout the year (Jones 1998).

In the Near East on the basis of ethnographic evidence it has been established that agro-pastoral communities use dung in fires to supplement the available firewood (Reddy 1998, Parker and Uzel 2007). Most often, dung cakes are prepared from collected manure, mixed with straw or other plant material for binding, and dried to be stored for use throughout the year. In terms of the heat produced and the storage potential, dung cakes are often seen to have a greater advantage over other forms of fuel (Anderson and Ertug-Yaras 1998). Through the burning of dung cakes in fire hearths or cooking ovens, the seeds consumed by livestock tend to preserve in the botanical samples (Charles 1998).

Bottema (1984) in a study of fire hearths in Syria noted that a majority of the botanical remains were derived from dung used as fuel. The plants that tend to survive the digestive tract and the burning tend to be wild/weedy taxa with thicker seed coats (for instance *Trifolium* sp.) and in some cases the straw used in making the dung cakes (Anderson and Ertug-Yaras 1998). It is noted that cereals, and other big seeded taxa in dung cakes tend to be poorly preserved compared to smaller seeded taxa.

3.3 Summary

There are various stages involved in the pre-depositional (crop processing), depositional (fire), and post-depositional (disturbance by humans or other animals) processes that lead to the formation of the botanical data in archaeological contexts prior to recovery by the archaeologists. Given our general understanding of these processes, it is highly likely that most of the plant materials that enter a site are not preserved. However, of those that are preserved, there is a higher chance of preservation for plants that are brought onto a site intentionally and exposed to fire intentionally. Of the plant remains that are brought into the site accidentally, those that appear in the same environments as intentionally gathered plants (e.g. weeds of cultivation) have a higher chance of being preserved.

In addition, plants that are in the same family tend to have similar preservation qualities when exposed to fire, and therefore taxa ratios in the same family may represent pre-depositional processes. For instance, a higher proportion of barley grains (hulled) compared to wheat grains (hulled) could indicate a higher frequency of use for barley grain. In addition, as discussed above, the relative proportions of wild/weedy taxa to crop species are likely to be lower as the crop goes through various stages of processing. Therefore, a cleaner crop will have less weeds and less chaff/straw, while a bigger proportion of weeds/wild taxa in the context would be in sizes and densities similar to the crop.

The relative proportions of fragmented and whole crop taxa could indicate poor preservation conditions indicating post-depositional disturbance, or the same measure could be indicative of depositional processes involved in food processing (i.e. grinding, pounding). In addition, due to their differential qualities under exposure to fire cereal crop grains and legumes would be expected to reflect different proportions in the archaeobotanical assemblage.

This chapter was devoted to the coverage of taphonomic processes, taken into consideration in subsections in order to deduce the possible signatures that can be left in the botanical assemblage. The methods of recovery, analysis and interpretation are discussed in Chapter 4 in order to address the biases and limitations involved in the production of the archaeobotanical record.

Chapter 4 Methods of Data Collection, Analysis and Interpretation

4.1 Retrieval

4.1.1 Recovery of Data in the Field

As a result of the processes discussed in Chapter 3, it is normally charred macro-remains that are dispersed non-randomly in archaeological deposits. Since the late 1960s water recovery techniques have been the most common method of retrieval of such material (Riehl 1999:16). Water recovery (also referred to as flotation) is a technique that separates plant material from the rest of the soil matrix using the differences in the densities of organic and inorganic material that allows for the less dense plant material to float while the denser mineral fraction sinks (Pearsall 2000: 62, Wagner 1988). To assist and speed up the disaggregation of plant remains from the soil, manual or mechanical agitation is used in various flotation systems. Of the mechanized flotation systems, perhaps the most commonly used in the Near East (and also the system used at Jerablus) is built from a 50 gallon tank, directing a steady flow of water into the tank with a water hose attached to the side that aids in separation of organic material from inorganic. It is noted that in a comparison of various techniques for the retrieval of charred plant materials, using this method of flotation, the rates of recovery of remains are extremely high (averaging to about 89% of the total sample on tests carried out) (Pearsall 2000: 82). On the other hand, in situ collection of materials without the use of water separation tend to overlook those plant remains that are smaller than the screen size for sorting sediment on site, and or tend to reflect a bias towards the higher recovery rates of highly visible plant remains such as corn cobs (Pearsall 2000: 83). Similarly, water sieving (the screening of sediment with the help of a water hose where the matrix is washed away through the screen), provides a crude method of recovery for more fragile plant materials

(Pearsall 2000: 80). Flotation of plant material in small quantities are usually carried out without the use of a high pressure water source where the agitation is provided manually by stirring or shifting the soil held in a mesh insert (also referred to as bucket flotation). This technique can provide a high rate of recovery, at times higher than manual flotation, but can be very labor intensive and unproductive with sample sizes bigger than a few liters (Riehl 1999:16).

Recovery biases are driven more by the sampling strategy employed rather than by the recovery technique used in the case of mechanized recovery systems. Due to the amount of time and labor required for the processing of sediment from sites, a sampling strategy is often employed to reduce costs. Total sampling (also referred to as blanket sampling) is the case when systematically chosen samples are taken in equal amounts from each context—often dismissed in large excavations due to the amount of work involved in processing (Jones 1991:68). More commonly, samples are chosen based on previous knowledge or expectations (judgmental or purposive sampling), where certain contexts known to yield botanical remains are targeted for sampling. Another approach is probabilistic sampling, where only randomly chosen contexts are sampled (Pearsall 2000: 69, Toll 1988). Of the mentioned sampling techniques, blanket sampling is often seen as the ideal, whereas purposive or probabilistic sampling produces more manageable sample volumes.

Features such as hearths or pits are often sampled heavily with purposive sampling, leading to a bias in the record that tends to reflect contexts where there is usually evidence of a fire (Dennell 1976: 230). As Toll (1988) mentions, contexts carrying low densities also add to our understanding of patterning in datasets, and are very important in analyzing the formation processes. Samples collected at Jerablus

Tahtani were selected based on purposive sampling strategies, for instance certain contexts that were expected to yield important plant materials, such as that of Tomb 302 at Jerablus, were sampled in greater quantities than samples that were representing mixed contexts or fills from the fortification.

4.1.2 Methods of Data Processing in the Lab

After the recovery of remains in the field, the botanical flots were processed in the lab, under a low power magnification stereomicroscope (10x-70x). Sorting of the samples was done systematically, looking at each fragment under the microscope in order to determine the identifiable specimens. For ease of sorting the Jerablus Tahtani samples, the flots were separated into two different size fractions with the aid of a geological sieve mesh size 1mm. The fractions >1mm were sorted in their entirety, while the <1mm fractions were divided into quarters and only ¼ of these were sorted. The separation of the sample into two fractions allows for the easier sorting of very small fragments and seeds of smaller size. Usually, the fragmented and small seed sizes associated with the <1mm samples require a great deal of time for the sorting of these portions of data with very little information available from them in terms of identifiable taxa. Van der Veen and Fieller (1982), propose that it is possible to estimate the representativeness of sub-sample seed counts and taxa range using simulation tests carried out on portions of samples sorted separately (and quantified separately) and in turn argue it is not necessary to sort entire samples to infer on taxa representation. A similar quantification method was used on one of the sorted samples from Jerablus, and the conclusions drawn from those will be discussed in further sections of this chapter.

4.2 Analytical methods

4.2.1 Methods of Identification

The sorted specimens were identified initially under the supervision of Dr. Sue Colledge who was in residence at Trent University during the 2009-2010 academic years. Published identification manuals (Nesbitt 2006, Jacomet 2008, Hillman 2001, Hillman *et al.* 1996, Hubbard 1992) were also consulted to aid preliminary identifications. Final identifications were made in consultation with the comprehensive Near Eastern botanical comparative collection at the Institute of Archaeology in London and in the British Institute of Archaeology in Ankara. The comparative collection housed in these institutions were collected by Professor Gordon Hillman in Turkey, Syria and Jordan. Species level identifications were possible if modern reference specimens of the complete range species within the genus as recorded in the published floras of the region were available in the collection. (*Flora of Turkey and the East Aegean Islands,* Davis 1965-1985, and *Flora Palaestina,* Zohary 1966, 1987, Feinbrun-Dotham 1978, 1986).

4.2.2 Methods of Quantification

Of the identified taxa, whole and intact specimens were recorded and counted as one (e.g. whole seeds, achenes, nutlets, spikelet forks, rachis nodes, and culm nodes). Indeterminate fragments of cereal grains, and legumes were recorded as well. Legumes with both cotyledons present were counted as one, one cotyledon present was counted as ½. Following the technique used by Colledge (2001), apical and embryo end fragments of cereals were counted and the higher number of the two was added to the number of whole specimens. Whole grain equivalents were calculated from the indeterminate cereal grain fragments by weight. For this, a standard weight measure of a cereal grain was calculated from 10 barley and 10 wheat grains and the average weight (0.008 g) was used in estimating the additional presence of whole cereal grains in each sample. Similarly, weight averages were calculated for barley (0.006 g) and wheat (0.009 g) and were used to estimate whole grain equivalents from indeterminate barley and wheat fragments. Due to the abundance of goat grass (*Aegilops* sp.) specimens, a similar approach was taken in their quantification, whereby whole specimens were counted; in addition to apical/embryo ends and a weight estimate from indeterminate goat grass fragments (avg. weight=0.004 g). Due to a low number of legume specimens present in the samples it was not possible to calculate a standard weight measurement for pulses and the quantification of these were left to whole grain counts. Other wild and weedy taxa were counted as one whole specimen if the fragment was greater than ½ of the seed.

The < 1mm flot fractions were quantified in a similar manner, whole items were counted and whole grain equivalents of cereals were added to these numbers. Since it was decided that only a fraction of the <1mm fractions would be sorted due to time constraints, two samples were sorted differently as a means of testing the efficiency of this system. One sample, C 161, was sorted in its entirety, without separating the flot into size fractions, which in turn proved to be extremely time consuming and inefficient due to the difficulty of sorting specimens of different sizes. Sample C 168 was sorted in entirety as well, however it was divided into two size fractions using a 1mm sieve. Sorting of the <1mm fraction was carried out in eight sub-samples, sorted and quantified separately. This exercise revealed that about 74% (20 out of 27 taxa) of the taxa present in the small fraction was identified within the first ¼ of the fraction (see Figure 4.1).

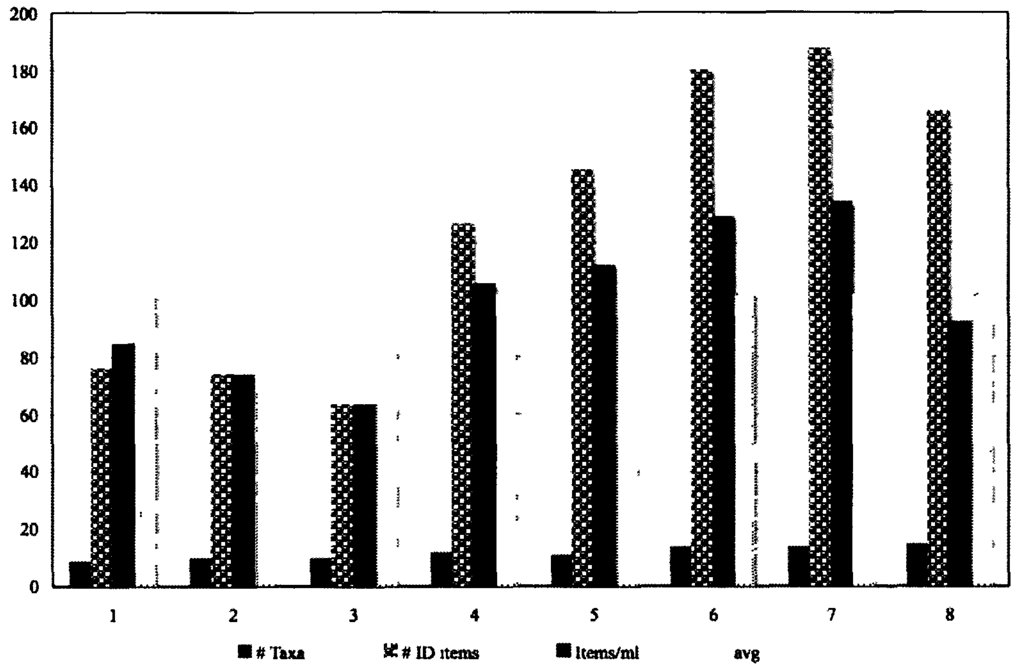

Figure 4.1 Number of taxa, number of identified items, items/ml, and the average number of items, 1-8 sub-samples of C 168

In addition, an assessment of the representation of number of identified items per sub-sample was made. As represented in Chart 2, distribution of number of identified items vary amongst the 1/8 sub-samples sorted, while items per milliliter of flot sorted come closer to predicting the actual number of items represented in the sample. Therefore, projection of the number of items in the sample are better carried out based on the number of items per milliliter of flot sorted, instead of multiplying the number of items by eight. This situation most likely stems from the variable volumes of the 1/8 sub-samples (ranging from 0.9 to 1.8 ml) and for the rest of the samples sorted, the <1mm ¼ fractions were translated into items/ml and then multiplied with the total sample volume to predict the total number of items in the <1mm fraction using the following formula:

Total # of items in <1mm fraction = [(Sub-sample # of items)/Sub-sample volume] x Total sample volume of <1mm fraction

Note that the variability in sub-sample volumes likely stem from the fact that sub-sampling was done in the lab without the aid of a riffle box since such a facility was not available.

A systematic method of quantifying taxa is useful for the comparison of taxa counts and ranges across samples and allows for the evaluation of botanical assemblages in relation to the context from which they were recovered. For this purpose various descriptive calculations were made in order to summarize the data generated through sorting. Total number of specimens and total number of taxa present per litre of soil floted were calculated for each sample as a means of comparing the abundance and the diversity taxa amongst the samples analyzed. In addition, when comparing taxa ubiquity, the percentage of samples in which specific taxa are present allows for a better understanding of the botanical assemblage in terms of patterning in relation to time period and the contexts from which the samples are coming.

In this respect, taxa diversity and density measures were calculated from total number of identified specimens in each sample (N) and total number of taxa present in each sample (S). An index of diversity was calculated for each sample following the Shannon-Weiner method (Krebs 1999:444) with the following formula.

$$\sum_{i=1}^{n} (p_i \ln p_i)$$

Where p_i is the relative abundance of any given species calculated by dividing the number of identified specimens from that species by the total number of specimens in each sample. The index H equals 0 when the sample contains only one taxon and increases with the number of taxa. As H increases, there is high species richness and evenness, and as H decreases there is low species richness and evenness. This index also allows for the evaluation of the even distribution of taxa in each sample, for instance, when the samples are dominated by one taxon the index decreases. When all the taxa are equally abundant, the index is at its maximum (Krebs 1989, Orton, 2000).

While a qualitative approach allows for interpretations on the relative importance of taxa and patterning, it is still limited in our understanding of the overall plant use at any given site due to taphonomic limitations as discussed in Chapter 3. In addition to the charred plant material sorted, the presence of dung fragments in samples were noted and as a means of comparison amongst samples, these fragments were weighed and the total weight per sample was recorded.

4.3 Interpretive Methods

4.3.1 Ecological and Agricultural Models

Interpretations of the taxonomic composition of assemblages of charred crops and wild taxa found on archaeological sites rely heavily on ecological models for early agricultural systems. Land management, sowing season, and the intensive/extensive nature of cultivation define specific ecological niches where crops and weeds grow. In this respect the ecological characteristics of weeds identified in assemblages signal to the habitat created through farming. Several crop species can tolerate a range of ecological conditions, and individually do not necessarily reflect the growing conditions in the field (Duarte 2007). The weeds growing alongside the crops in the same fields can however be good indicators of agricultural practices (such as irrigation, tilling etc.) (Bogaard 2004:

21). For instance the timing of the flowering period of weeds can signal to the sowing season or to the availability of water in the fields.

There are various definitions of weeds, depending on the discipline, but most commonly the term refers to wild, unwanted plants that tend to have an intrusive nature (Bunce and Howard 1990). It is noted by many authors that whether or not a species is considered a weed is dependent on cultural factors, for instance a plant of economic value in one culture might be considered a weed in another culture (Bogaard 2004: 22). There are three major theoretical models used to interpret weed/wild seeds found in archaeological sites along with crops. The earlier models, phytosociology and autoecology, have now been refuted by some archaeobotanists in favor of the functional interpretation of botanical surveys (FIBS) (Bogaard 2004, Jones *et al.* 2010, Charles *et al.* 1997, Charles *et al.* 2003).

Phytosociology, as an ecological approach, takes into account the behaviors of "plant communit[ies]" as opposed to the characteristic behaviors of individual plants (Küster 1991:17). This approach, in its application to archaeobotany has been criticized by many (Hillman 1991, Bogaard 2004, van der Veen 2007) due to taphanomic factors. It is often difficult to account for single episodes of deposition in botanical assemblages, making it hard to predict whether one or many plant communities are represented in a given assemblage. Autoecology, on the other hand, examines the characteristic behaviors of individual species within specific ecological conditions (van der Veen 1992). This approach, based on the early work of Ellenberg (1950), uses various attributes assigned to each species based on their responses to conditions such as light, moisture, soil composition, temperature, etc. However, since the attributes are created by observations made on present day taxa, it is questionable whether these are applicable to archaeological remains (Bogaard 2004: 6).

FIBS as an analytical tool has been developed by Hodgson and Grime (1990), heavily reliant on the autoecology approach. This method combines various ecological theories and uses attributes of species that are tolerant of similar conditions and groups them into "functional types" (Charles *et al.* 1997: 1152). In this sense, this approach combines previous methods to model ecological conditions by looking at weed-crop assemblages, but is not strictly bound to groups, or individual species of weeds, rather to the distribution of specific attributes (Bogaard 2004: 7, Jones *et al.* 2010). In essence, by looking at the composition and the distribution of weed ecologies, this model seeks to identify farming systems, especially inferences relating to irrigation and field maintenance (Charles *et al.* 1997).

The aims of previous applications of FIBS to archaeobotanical samples have included the identification between irrigation and dry-farming (Charles *et al.* 1997 in Spain, Charles *et al.* 2003 in Jordan), fallowing and field rotation (Palmer 1998, Bogaard *et al.* 1999 in Jordan), intensive and extensive farming (Jones *et al.* 1999 in Greece), and timing of crop planting (Bogaard *et al.* 2001, Bogaard *et al.* 2011 in Germany). Recent syntheses of the previous work (Jones *et al.* 2010, Charles *et al.* 2010) mention the interregional applicability of the FIBS attribute data in determining intensive vs. extensive farming methods, noting that it is more advisable to use local attribute data in determining watering regimes, since these tend to vary depending on climate and rainfall zones (Jones *et al.* 2010:70-71).

In order to test the presence/absence of irrigation at Jerablus, attribute data were entered from the available local floras mentioned earlier in the chapter, with attention paid to the flowering season and the flowering duration of the plants. If most of the crops in the samples are autumn planted, and harvested in the early summer, it is assumed that the summer drought season would select against weed species that require a summer growth season and/or a longer flowering duration with a higher water requirement. Hence, the presence of summer flowering weed taxa would be an indication of watering and/or irrigation regimes (Charles *et al.* 2003). At the same time later flowering weedy taxa could be signaling to a spring sowing regime (Jones *et al.* 2010).

4.3.2 Statistical Methods

In order to answer the research questions outlined in Chapter 1, multivariate techniques were used on archaeobotanical data available from Jerablus Tahtani. Correspondence Analysis (CA) is a very suitable method for semi-quantitative (presence/absence) and abundance data with many zero values (Gauch 1982: 37, Shennan 1997: 308). In addition to multivariate analyses, the data obtained from the ten sorted samples from Jerablus was evaluated on qualitative and quantitative levels by measures of density, taxa diversity, and taxa abundance. Documenting the presence/absence of taxa provides an opportunity to infer on the seasonality of site occupation and diet without heavily relying on the percentage representations of each taxon, thus creating a generalized picture of the composition of the assemblage.

On the other hand, relying solely on descriptive analyses hinders the evaluation of the importance of certain species either in the diet or in other plant use activities. For instance, as mentioned by Popper (1988), relying solely on absolute counts of taxa (the number identified specimens of each taxon) can give a distorted view that is likely to represent the effects of formation processes on the archaeobotanical record. In cases where the numerical presentation of each taxon is distorted by the formation processes, ubiquity proves to be an effective measure in analyzing the overall presence of taxa at a site (Pearsall 1988). As mentioned above, diversity indices (the Shennan diversity index, H) provide a useful tool for the analysis of overall sample composition in analyzing the variety of taxa present and their distributions.

Furthermore, to assist in the detection of patterning inherent in the botanical samples Correspondence Analysis, a multivariate technique in statistical data mining, was used. CA is a statistical method of ordination that arranges samples on multiple axes on the basis of their combined attributes. In essence, CA provides a visual summary of botanical data displaying the species distribution across several samples (Bogaard 2004: 93, Gauch 1982: 218). Ecological data in general are very complex and present certain problems regarding statistical analyses, this stems from the general tendency of these data to be complex due to natural variation (Gauch 1982: 13, Jongman, Ter Braak, and Van Tongeren 1995: 26). In addition, as discussed in Chapter 3, various formation processes make archaeobotanical samples prone to a great degree of noise. Noise in statistical analyses is described the tendency for the data to display a high degree of variation due to chance, and cannot be attributed, or explained by other variables (Gauch 1982: 7). In this sense, the analyses carried out on weed ecology data had to be altered in order to make this dataset suitable for analysis.

In order to use CA, data from each sample was simplified to include presence/absence scores (1/0) from species that are represented in at least 1% of the overall sample in order to avoid outliers. Additional plots were drawn from percentage representations of major categories such as cereals, pulses/legumes, wild grasses, etc. in order to evaluate patterning in crop species across time. Along with the overall sample compositions, this approach also allows for the evaluation of context types and how these reflect different ubiquities and frequencies of taxa.

In the next chapter a full description of results is provided.

Chapter 5 Results

5.1 Sample Description and Contexts

Ten botanical samples from the Jerablus Tahtani were sorted and analyzed. This resulted in a total of 8211 identified items representing 83 different taxa (see Table 5.2 below). Potential differences between samples were examined in two ways: first the amount of charred material represented per liter of soil processed in the field (i.e. density of charred material), the number of identified specimens and the number of different taxa was calculated for each sample. Second, species richness and abundance were calculated for each sample using the Shannon Index for diversity as explained in Chapter 4. For a full list of taxa counts see Table A.1 in Appendix. Table 5.1 provides a summary of sample provenience.

Chronology	Sample	Area	Unit	Period	Context
Local Late Chalcolithic	C 155	III	2194	1A	Upper layer of pit 2195
	C 205	III	2610	1A	Deposit above hearth 2737
	C 181	III	2482	1A	Fill of pit 2485
Uruk	C 168	III	2393	1B	Occupation deposit above building 2185
	C 144	III	2012	1B	General fill from slope wash
Early Bronze Age, earlier	C 59	III	976	2A	Occupation deposit from the destruction layer of building 1006
	C 161	III	2319	2A	General deposit below building 2242
	C 160	III	2307	2A	Fill of pit 2317
Early Bronze Age, later	C 186	IV	2387	2B	Fill of drain 2386
	C 149	IV S2	2059	2B	Fill of pit 2168, above tannur

Table 5.1 Summary of samples, chronology, excavated units, and contexts

5.1.1 Contexts and charred material densities

As the figures in table 5.2 show, the densities of charred remains (high: 1.26, low: 0.1, mean: 0.5) and number of identified specimens per litre of soil (high: 67, low: 4, mean: 19), and total number of identified specimens in each sample (high: 2320, low: 144, mean: 821) vary greatly across the 10 samples. The absolute number of different taxa identified in each sample range from 17 to 54, with 83 taxa represented across ten samples.

Period 1A

Three samples were analyzed from contexts dated to the earliest period (1A): C 155 (200 litres), C 181 (35 litres) and C 205 (35 litres). All three of these samples had lower densities than the overall mean of the ten samples studied, in addition to below average total number of identified specimens. C 155 and C 181, have the lowest density values and the lowest Shannon index values. These two samples were taken from the same occupation level and from two different pits (pit 2195 and 2485 respectively), and were associated with the pre-construction phase of an important Uruk period building (B 2185). Sample C 205, which was taken from the ashy deposit above hearth 2737, has a slightly higher density of charred material and items/litre of soil compared to C 155 and C 181, however is still below the overall mean for both values.

Sample	Period	Flot Vol. (ml)	Volume Floated (l)	Density (ml/l)	# ID Items	Items/l	# Taxa	Shannon Index
C 155	1A	21.0	200	0.11	794	4	22	1.8
C 205	1A	10.8	35	0.31	353	10	29	2.0
C 181	1A	3.5	35	0.10	163	5	17	1.7
C 168	1B	44.0	35	1.26	2328	67	54	1.7
C 144	1B	32.5	200	0.16	975	5	29	2.1
C 59	2A	24.5	40	0.61	144	4	23	2.2
C 161	2A	15.0	25	0.60	495	20	32	2.4
C 160	2A	16.3	25	0.65	728	29	30	2.1
C 186	2B	29.8	35	0.85	1124	32	43	2.5
C 149	2B	37.0	100	0.37	1107	11	41	2.7

Table 5.2 Samples analyzed, volumes, density, number of identified items and number of taxa per sample

Period 1B

From the later part of the Late Chalcolithic (period 1B) two samples were analyzed: C 144 (200 litres) and C 168 (35 litres). Sample C 144, taken from the general hillwash leading to the eastern end of the mound, has a very low density score, whereas C 168 yielded the highest density of charred material in amongst the ten samples analyzed, with a wide range of taxa represented. This sample was taken from above a clear occupation layer in B 2185 and the high density and the diversity represented by this sample could be indicative of the nature of botanical deposits in and around building floors close to fire features. Both samples have above average total number of identified specimens amongst the ten samples analyzed.

Period 2A

Three samples were analyzed from period 2A, the earlier phase of Early Bronze Age: C 59 (40 litres), C 161 (25 litres), and C 160 (25 litres). All three samples from this period have above average density measures; however all three have below average total number of identified specimens. C 161 and C 160 have above average specimens per litre of soil processed, however, sample C 59, taken from the destruction level of one of the Early Bronze Age buildings (B 1006), have one of the lowest number of specimens per liter amongst the ten samples analyzed. This sample, similar to other samples taken from adjacent contexts (Murray 1996: 20), is predominantly composed of charred wood remains indicative of a widespread burning event in the area surrounding B 1006 during this period.

Period 2B

Two samples were analyzed from period 2B: C 186 (35 liters), and C 149 (100 liters). C 149, taken from the fill of pit 2168, a context associated with a tannur feature has a below average charred material density, and a below average value of items/litre. On the other hand, C 186 taken from the fill of drain 2386, containing various cultural items such as pottery sherds, flint, discs, and querns, has an above average density value and items/liter. Both samples have above average total number of identified specimens amongst the ten samples analyzed.

General Observations

As described above (also see Table 5.2), charred material densities and items per liter vary greatly across these samples. While some of the lowest densities come from samples from general fill of pits or slope-wash (i.e. C 155, C 181, C 144), the highest density in the samples analyzed comes from the occupation layer deposit of B 2185 (sample C 168). Most samples taken for flotation are in the range of 25-40 liters, and there seems to be no apparent correlation between the sizes of the samples floated (liters) and the volume of the flots (ml) (processed soil samples analyzed in the lab). On the other hand, there is a strong positive linear correlation between the volume of the flots (ml) and the number of identified specimens from each sample (Figure 5.1).

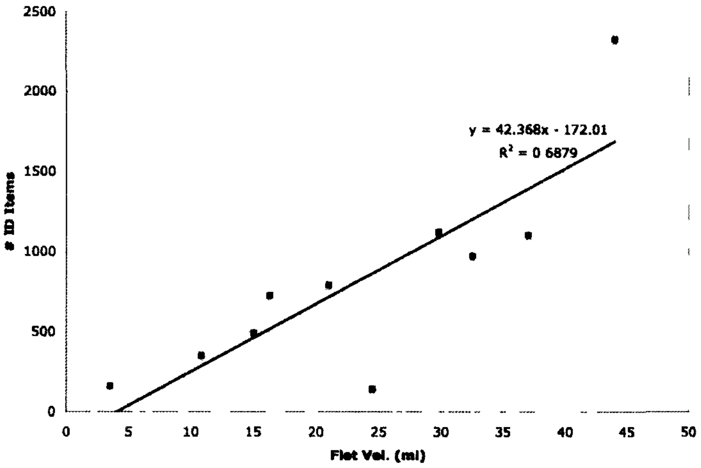

Figure 5.1 Flot volume and number of identified items in the samples analyzed from Jerablus (R^2=0.69)

In addition, the range of taxa represented in each sample is positively correlated with the number of identified specimens in the samples (Figure 5.2). Species richness indices, calculated using the number of taxa and the distribution of taxa abundances, are thus skewed by the volume of the flots.

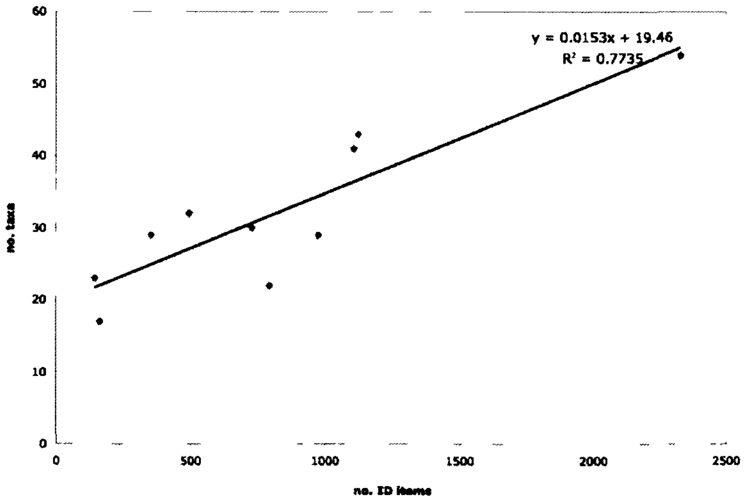

Figure 5.2 Number of identified items and number of taxa in the samples analyzed from Jerablus (R^2=0.77)

As mentioned in Chapter 4, the Shannon index allows for the quantification of species richness and evenness across several samples originating from similar ecosystems. Lower values (closer to 1.5) represent ecosystems with either low evenness or low species richness, whereas higher values (closer to 3.5) indicate even distribution of species across taxa, and/or higher numbers of different taxa present. As the calculated values (see Table 5.2) reflect, all ten samples cluster around the 1.7-2.7 range, reflecting on a general scale low species richness or evenness. The samples with the lowest scores reflect either those that have a limited range of taxa (low species richness i.e. C 155, C 181) or those that have uneven distributions of the abundance of each taxa (C 168). The lower spectrum of the indices ranging from 1.7 to 2.1 belong to samples coming from the Late Chalcolithic (period 1A and 1B), where the Early Bronze Age samples all display higher richness values (period 2A and 2B).

This situation reflects that the samples dated to the 1A and 1B periods show either a fairly low range of taxa, and even if a bigger range is represented (as in the case of C 168) a relatively high emphasis is put on a limited number of taxa. In fact, the average number of taxa of the samples from the Late Chalcolithic (thirty different taxa) is lower than the Early Bronze Age average, despite the presence of C 168 with fifty-four different taxa in the Late Chalcolithic. On the other hand, the range and distribution of taxa are different in the Early Bronze Age samples, reflecting on average more taxa represented, and more evenly distributed abundances of these taxa in samples. The distributions of major taxa groups will be discussed in Section 5.2 with relation to shifts over time periods, and contexts.

5.1.2 Additional Jerablus Tahtani Samples

Additional data on samples analyzed in the previous years, which have been taken from published site reports and unpublished studies, and have also been reviewed and incorporated into the analysis of the ten samples studied as part of this dissertation. In previous years preliminary botanical reports were published along with the annual site reports (see Murray 1995, 1996). Studies at this stage were very limited and detailed accounts of sample analyses are not available. However, it is noted that in terms of sample composition, cereals are the most abundant and the most ubiquitous taxa (Murray 1995, 1996). In addition, samples from various contexts have provided evidence of crop storage (of barley and lentils in different contexts), crop processing, and evidence of wood and dung used as fuel (Murray 1995:24-25, 1996:20-21).

Tomb 302

I was allowed access to an unpublished report produced on twelve samples from the mound tomb complex, T 302, by Colledge and Stevens (forthcoming). The authors note that the compositions of samples from T 302 do not reflect a markedly different composition in nature compared to other domestic contexts. In this sense, it is very useful to compare the ten samples analyzed to those studied from T 302. Twelve samples from various parts of T 302 (see Table 5.3) were collected in order to compare plant material from discrete contexts within the mound.

Sample	Area	Unit	Context	Density (ml/l)	Items/l
C 55	II	697	Annex	0.06	0.7
C 25	II	503	Entrance	0.04	1
C 28	II	567	Entrance	0.06	2
C 24	II	385	General	0.40	9
C 31	II	385	General	1.00	4
C 34	II	410	General	0.12	5
C 30	II	410	Main chamber phase 1	0.14	4
C 36	II	410	Main chamber phase 1	0.54	20
C 18	II	656	Main chamber phase 3	0.63	2
C 19	II	656	Main chamber phase 3	0.38	1
C 27	II	385	Main chamber phase 3	0.12	10
C 26	II	512	Mound	0.06	3

Table 5. 3 Summary of contexts and flot densities of the T 302 samples

T 302 is a burial mound located in Area II of the site, dating to the Early Bronze Age period (2A, 2B) that was flooded periodically by the Euphrates (Peltenburg 2007). Due to the frequent flooding events there were several re-building activities at T 302, reflected in the botanical remains originating from these contexts that indicate mixing with general fill and occupational deposits. Colledge and Stevens (forthcoming) report that the mean density of charred material in samples at T 302 is very low (0.3 ml/liter), which is in fact lower than the mean density analyzed by the researcher (at 0.5 ml/liter). These low densities along with the taxonomic composition of the samples seem to confirm that the T 302 samples do not represent a specialized context (Colledge and Stevens forthcoming).

5.2 Sample Compositions

In most samples (eight out of ten) and based on abundance values (number of identified specimens) the assemblages composed of cereals by more than 60%, with legumes/pulses in very low percentages (see Table 5.4 below). Wild grasses, including

Aegilops sp. (one of the more abundant wild grasses in the assemblage), have varying abundance and ubiquity across samples, but never more than 20% of the overall sample. Other wild and weedy taxa usually are represented in low proportions of the sample, with the exception of C 168 where small seeded (wild) legumes comprise 64% of the overall sample size (see Table 5.4 for a breakdown of sample components). Common weeds such as *Chenopodium* sp., *Galium* sp., *Eremopyrum* sp., and other wild species such as *Ajuga/Teucrium* spp., *Buglossoides incrassata* are also present in the samples. The range of wild/weedy taxa seems to confirm with previous preliminary botanical reports from Jerablus (Murray 1995, 1996).

Sample	Cereals %	Legumes/ Pulses %	Wild Grasses %	Other Wild/Weedy Taxa %
C 155	68.9	0.3	0.0	30.9
C 205	73.1	0.3	5.4	21.2
C 181	71.8	0.0	1.2	27.0
C 168	9.6	0.1	2.7	87.7
C 144	62.6	0.6	19.1	17.7
C 59	32.1	0.3	8.0	59.6
C 161	70.9	2.4	17.2	9.5
C 160	69.5	0.1	12.5	17.9
C 186	64.9	2.8	6.7	25.7
C 149	74.1	2.4	9.1	14.4

Table 5.4 Composition of samples as represented by percentage presence values of cereals, legumes/pulses, wild grasses and other wild/weedy taxa

5.2.1 Crops

As mentioned above, crops are predominant in all ten samples and cereals are the most ubiquitous and abundant. As explained in Chapter 4, identifications of cereal grains were made according to published identification guides (Jacomet 2008, Hillman 2001, Hillman *et al.* 1996, Hubbard 1992).These identifications were confirmed by consulting the modern reference collection housed in the Institute of Archaeology at the University College London. Domesticated hulled barley (*Hordeum vulgare*) was identified without making a distinction between two-row and six-row barley due to limitations of poor preservation for most grains in addition to the lack of well-preserved rachis fragments.

In most cases, a clear distinction between einkorn (*Triticum monococcum*) and emmer (*Triticum dicoccum*) was not possible due to the poor preservation of grains, and the absence of well-preserved spikelet fragments. Therefore, most of the domesticated hulled wheats were identified as *T. monococcum/dicoccum* (einkorn/emmer wheat). Additionally, in low quantities emmer *T. dicoccum* and free threshing wheat (*Triticum* spp. free threshing) were identified.

Hordeum vulgare (hulled barley) and *Triticum monococcum/dicoccum* (hulled wheat) are the most ubiquitous crops (present in 100% of samples), while *Lens* sp. (lentil) is present in only 60% of the samples (see Figure 5.3). Although *Lens* sp. and *Linum* sp. (flax) have relatively high ubiquity (e.g. present at least half of all the samples analyzed) , these two taxa are represented in the samples in low numbers. As can be seen from the ubiquity scores and from percentage abundances, pulses are represented in low numbers in the botanical assemblage, comparable to results from Tomb 302 (Colledge and Stevens forthcoming). Even though pulses are represented in small numbers in the samples analyzed for this study, earlier botanical reports by Murray (1995, 1996) indicate the presence of storage and crop processing areas with a high numbers of lentils recovered. *Vitis vinifera* (cultivated grape), with a low ubiquity, is the only fruit crop in the samples.

The only significant finding of grape comes from sample C 59, comprising 39% of the entire sample by abundance.

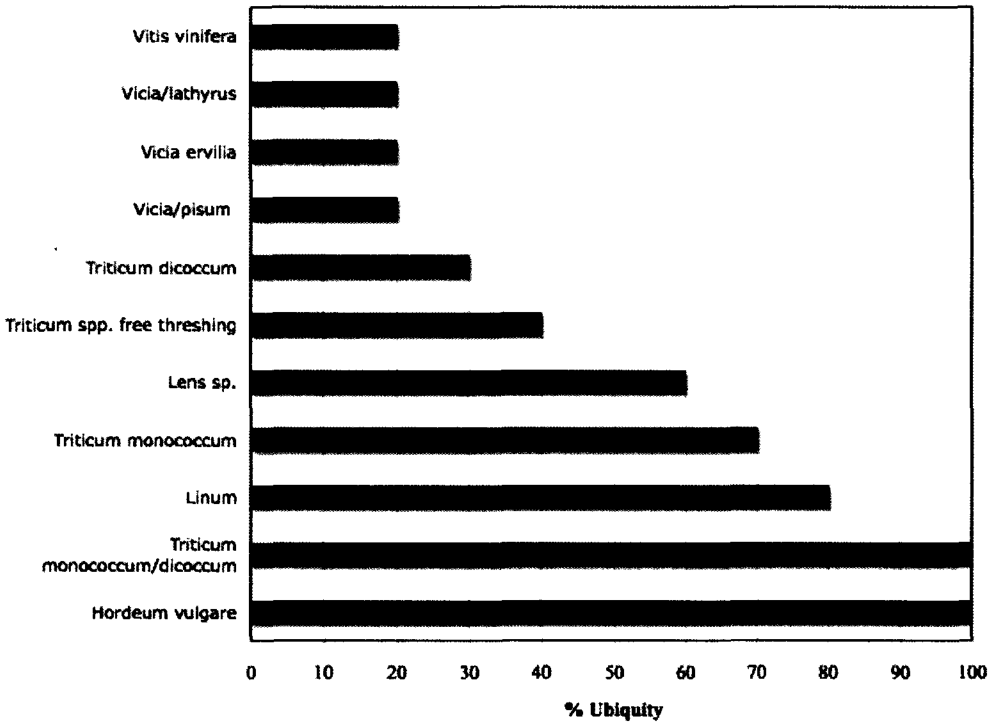

Figure 5.3 Ubiquity scores for crop taxa

Looking more closely at the composition of cereals, in seven out of ten samples indeterminate cereal fragments comprise more than 50% of all cereal remains (see Table 5.5). Grains of *Hordeum* sp. and *Triticum* sp. are present in lower proportions of all cereals. When grain and rachis or spikelet fragment counts are combined, half of the samples reflect higher proportions of barley to wheat, while there are higher percentages of barley grains in 80% of the samples, and higher percentages of wheat rachis in 70% of the samples.

Sample	*Triticum* sp. grains %	*Triticum* sp. spikelet fragments %	*Hordeum* sp. grains %	*Hordeum* sp. rachis %	Cereals indet %
C 155	8.8	0.0	14.3	0.0	77.0
C 205	5.4	1.2	17.8	2.7	72.9
C 181	6.0	0.0	12.8	0.0	81.2
C 168	3.7	42.5	9.9	0.0	43.9
C 144	11.8	5.4	10.2	0.0	72.6
C 59	26.1	6.5	19.6	0.0	47.8
C 161	10.0	25.0	19.4	0.9	44.7
C 160	4.5	16.6	5.7	0.0	73.1
C 186	4.4	9.6	15.1	5.9	65.0
C 149	5.4	12.9	20.1	10.2	51.3

Table 5.5 Composition of cereals as represented in the percentage distribution of the total cereals component in each sample

The uneven distribution of wheat spikelet fragments and barley rachis fragments could be suggesting different crop processing techniques as mentioned in Chapter 3, hulled wheat was possibly stored as a whole ear, whereas hulled barley would have been stored in cleaned grain form. Hulled barley storage contexts from Jerablus seem to confirm the preferential storage of this crop after being cleaned from rachis elements (Peltenburg *et al.* 1995). Such practices would have resulted in lower abundances of barley rachis, and higher abundances of wheat spikelet elements. However, storage practices of cereal crops do not explain the uneven representation of barley and wheat grain. Therefore, in evaluating the overall abundance of hulled barley and hulled wheat, grain counts and quantified rachis/spikelet fragments were combined to get a general idea of the proportions of each crop species. There is more hulled barley (grains and rachis added) represented in all samples analyzed dated to the 1A and 2B periods than hulled wheat (grains and spikelet fragments added). Meanwhile, there are higher proportions of wheat (grains and spikelet fragments added) represented in all samples analyzed dated to the 1B and 2A periods (see Figure 5.4).

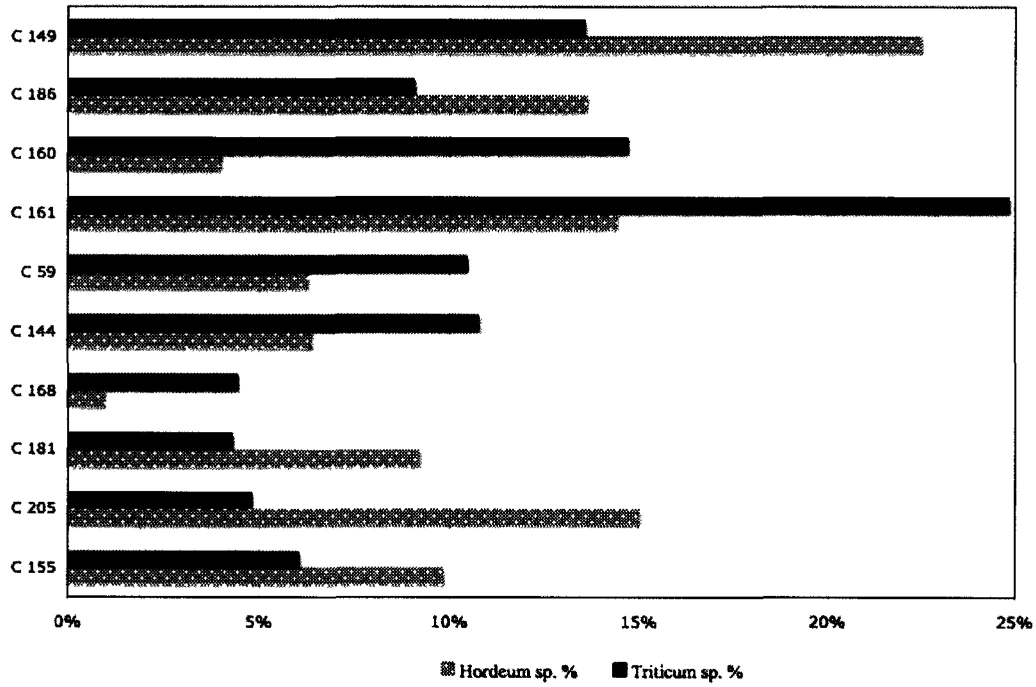

Figure 5.4 Percentage abundance values of barley and wheat across samples.

As mentioned earlier, a great proportion of cereals in the assemblages are indeterminate grains and fragments. In fact, cereal fragments outnumber whole grains. Table 5.6 shows the total number of whole grain equivalents (for all fragments and calculated on the basis of weight averages of whole grains as explained in Chapter 4) compared to total number of whole grains from all cereal taxa (e.g., identified to species, genus or family). This indicates that cereal remains are highly fragmented in all the samples analyzed.

Whether high fragmentation of cereal grains is correlated with food processing or with post-deposition taphonomy is unclear. The three samples with much higher fragmentation ratios (C 144, C 59, and C 160) also have higher percentages of wheat compared to barley.

Sample	Number of cereal fragments	Whole grain equivalent of cereal fragments	Whole grains	Ratio fragments/whole
C 155	2170	473	74	6
C 205	1732	217	31	7
C 181	520	103	14	7
C 168	1353	112	15	7
C 144	2110	526	51	10
C 59	80	41	2	21
C 161	1789	216	31	7
C 160	2282	383	36	11
C 186	2650	511	104	5
C 149	2105	464	120	4

Table 5.6 Fragmentation ratios of cereals

5.2.2 Wild/Weedy Taxa

Wild and weedy taxa account for a majority of the taxa range in the samples, but are present in much lower proportions. The most ubiquitous wild/weedy taxa are small seeded Leguminosae (present in 100% of the samples), *Aegilops* sp. (goat grass) and *Buglossoides tenuiflora* (both present in 90% of the samples) (see Figure 5.5). Small seeded legumes and goat grass also make up a greater portion of the wild/weedy taxa in most samples. There is also a notable amount of goat grass chaff present, especially in samples C 144 and C 149. It was not possible to identify most of the small seeded Leguminosae to species level. Butler (1996) reports that it is often challenging to identify these taxa to species/genus level, whether archaeological or modern specimens, due to the high degree of variability in seed morphology in and amongst species of this family.

In addition to goat grass, there are various other common steppic grasses and field weeds present in the samples such as *Lolium* sp., *Bromus* sp., and *Eremopyrum* sp., are present in the samples, although in much lower amounts. Three species from the

Boraginaceae family were identified, *Buglossoides incrassata*, *Buglossoides tenuiflora*, and *Arnebia decumbens*. This family is considered to be potential contaminants in archaeobotanical assemblages due to their high silica content that allows their preservation without fire exposure (uncharred), and that when exposed to fire these specimens tend to turn white or gray instead of black (Miller 1991). In this study, the uncharred specimens of this family were counted and scored separately as Boraginaceae uncharred.

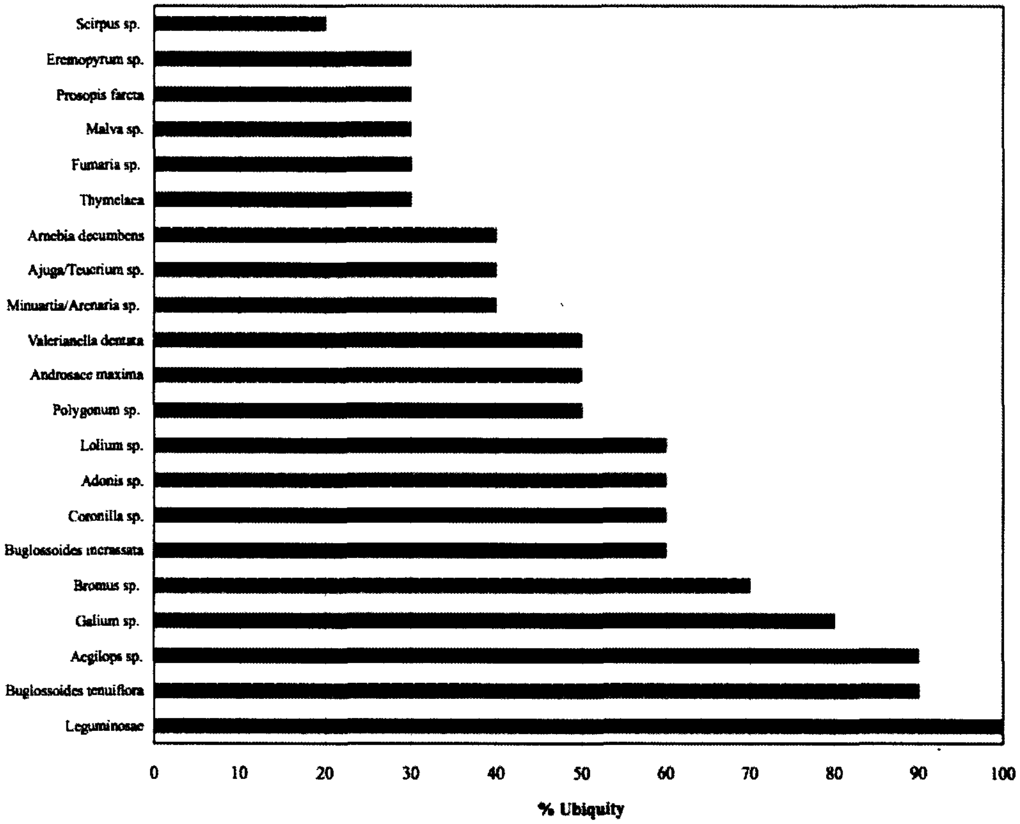

Figure 5.5 Ubiquity scores for wild/weedy taxa

5.2.3 Dung

Fragments of animal dung are present in 80% of samples analyzed for this study. In addition, previous studies report that several other samples from Jerablus contain dung fragments (Colledge and Stevens forthcoming, Murray 1995, 1996). Dung fragments have a distinct amorphous structure and tend to char unevenly appearing brownish/red rather than black (Charles 1998, Shahak-Gross 2011). It is often not possible to determine the species of animal that these fragments belong to, unless the piece was preserved as a whole, in which case it would be possible to differentiate between caprine and bovine dung (Charles 1998). The presence of burnt dung in samples indicates that dung could have been used as a fuel in domestic hearths/ovens, therefore would have been collected from livestock grazed on fallow fields/pastures or fed a selection of collected fodder. As mentioned in Chapter 3, it is possible for seeds to be preserved after passing through the gut of animals, and thus being present in dung used as fuel. Therefore, a number of taxa identified in these samples could have been gathered as fodder, or would have been growing in fallow fields or pasture areas for animal grazing. It is important to note that the sample with the highest amount of dung, C 168 (9.8 gr/44 ml), also displays the greatest range of wild/weedy taxa and the sample is dominated by small seeded Leguminosae.

5.3 Statistical Analyses

5.3.1 Sample compositions

Correspondence analysis based on abundance percentage values (number of items of one taxa/total number of items identified x 100) of taxa and presence/absence scores were carried out on the samples analyzed to see if there was patterning in the data. In addition, further tests were run on data including Tomb 302 contexts in order to assess the nature of botanical assemblages in relation to different context types. Preliminary pattern searching was done based on proportion values (converted into percentages) from main taxa categories (cereals, pulses/legumes, wild grasses, other wild/weedy taxa) with twelve samples from the Tomb 302 (C 18 to C 55) contexts and the ten samples analyzed for this study (C 59 to C 205) (see Figure 5.6). While the latter 10 samples tend to disperse along the x-axis (Dim 1) with sample C 161 at -0.4 and sample C 168 at 1.3, samples originating from Tomb 302 show a slight dispersion along the y-axis (Dim 2) with sample C 26 at -0.3 and sample C 30 at 0.7. The patterning of the Tomb 302 samples is more closely related to the proportions of legumes/pulses and wild grasses, whereas the patterning of the ten samples analyzed for this study is more closely affected by the proportions of cereals.

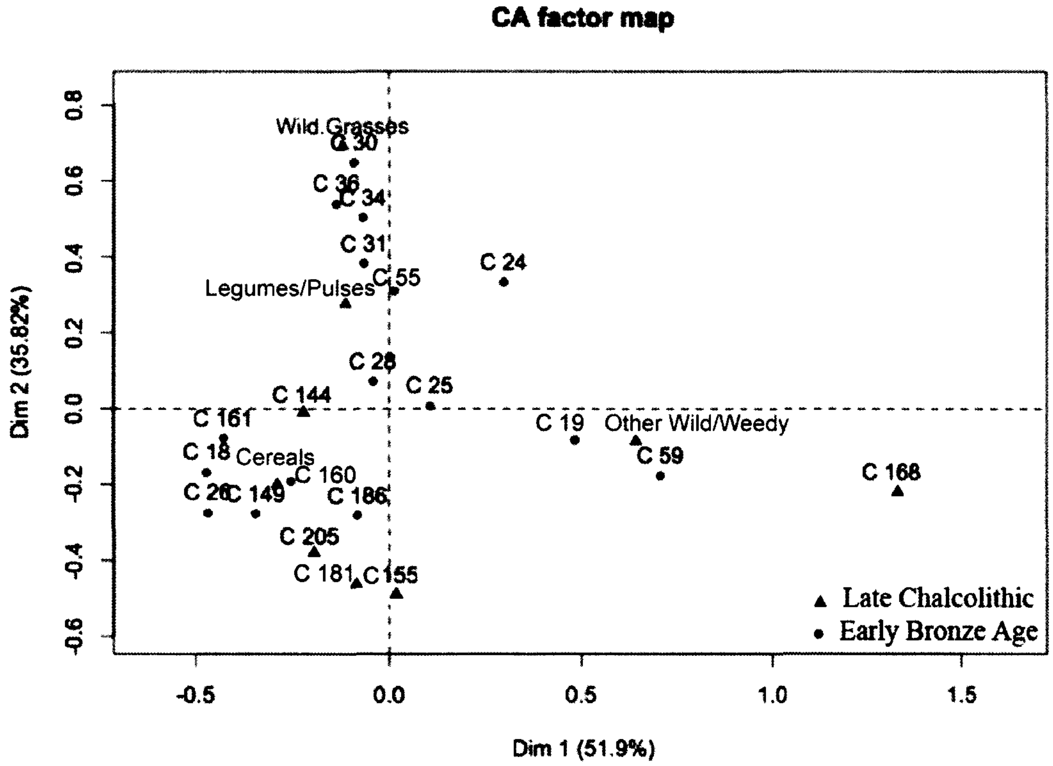

Figure 5.6 CA plot of 22 samples from Jerablus Tahtani with percentage abundance values of cereals, pulses/legumes, wild grasses, and other wild/weedy taxa

It should be noted that, along axis 1 (Dim 1) accounting for 51.9% of the variation, a majority of the samples are on the negative side of the axis, with only C 59, C 168, C 24, and C 25 on the positive side. Most Tomb 302 samples disperse along axis 2 (Dim 2), and their patterning is more closely related to the proportions of legumes/pulses. In terms of taxa, cereals are on opposite sides with legumes/pulses and wild grasses on axis 2. While other wild/weedy taxa are on the opposite side of cereals on axis 1. As can be seen from the figure, most of the samples are clustered in the negative side of axis 1, and in this case, it is likely that the high values of other wild/weedy taxa in the composition of samples C 59 and C 168 are obscuring results.

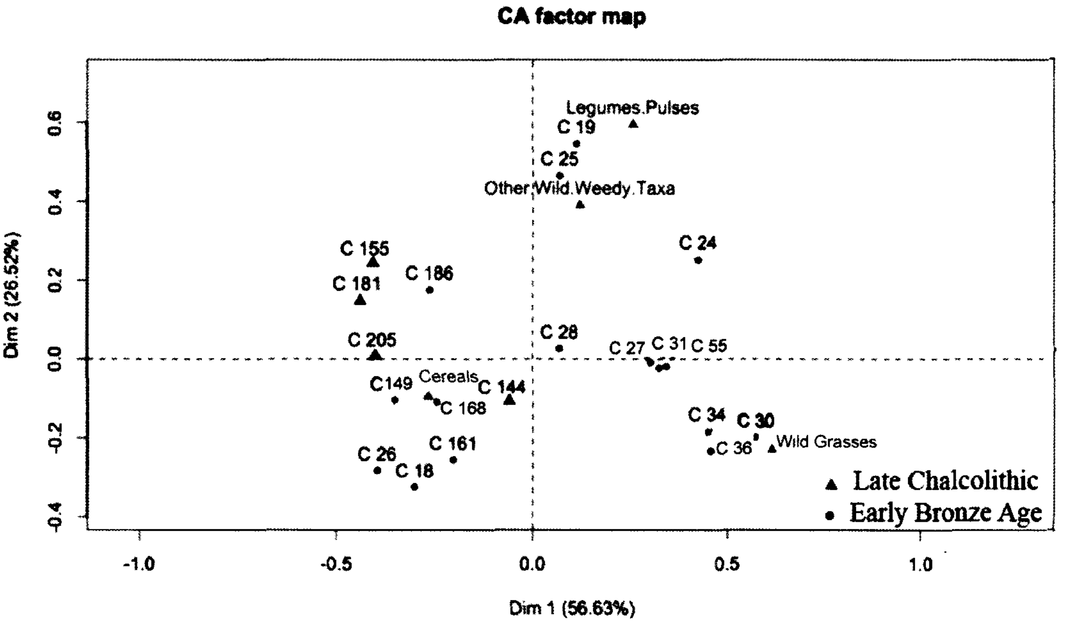

Figure 5.7 CA plot of 20 samples from Jerablus Tahtani (excluding C 168 and C 59) with percentage abundance values of cereals, pulses/legumes, wild grasses, and other weedy taxa

Therefore, further examination, excluding C 59 and C 168 from the dataset, produced a slightly different CA plot (Figure 5.7). Similar to the interpretation of Figure 5.6, this CA plot also shows a division between a majority of the T 302 samples and the samples analyzed for this study. On the x-axis (Dim 1), accounting for 56.6% of the variation in the patterning, all samples from T 302, with the exception of C 26 and C 18, are on the positive side of the axis, on the opposite side of the samples analyzed for this study (C 144 to C 205, please note that C 59 and C 168 were excluded in the CA plot for Fig. 5.7). On Dim 1, the contribution of the proportions of cereals to the patterning in most pronounced in samples C 144, C 149, C 160, C 161 and two T 302 samples: C 26 and C 18. The mentioned T 302 samples (C 18 and C 26) were clustered closer with samples not coming from T 302 in Fig 5.6 as well. In this case (Fig 5.7), among the samples analyzed for this study, there is a slight separation between the Late Chalcolithic samples and Early Bronze Age samples while samples C 155, C 181, C 205 (all from period 1A) stand opposite C 149 (2B), C 160 and C 161 (2A). The CA plot excluding C 59 and C 168 (Fig. 5.5) shows a stronger separation between T 302 samples, while some samples are more closely patterned with legumes/pulses and wild/weedy taxa, others (standing on the opposite side of axis 2) are in a closer relation to proportions of wild grasses.

Further analyses on the composition and patterning of samples were carried out with the ten samples analyzed for the present study (C 59 to C 205). Looking more closely at the composition of cereals in these samples, it is possible to evaluate the relationship of crop processing waste and grains in addition to the distribution of cereal crops across samples (see Figure 5.8 below). CA was used on proportion percentages of *Hordeum* sp. elements (rachis and grains), *Triticum* sp. elements (rachis and grains), indeterminate cereals (whole and fragmentary) and *Aegilops* sp. elements (rachis and grains). This plot accounts for a cumulative variance of 77.8% in the patterning of the samples. Barley and wheat (total abundance % of rachis and grain elements in each sample) stand opposite each other on both axes 1 and 2, indicating that these taxa pattern differently across samples.

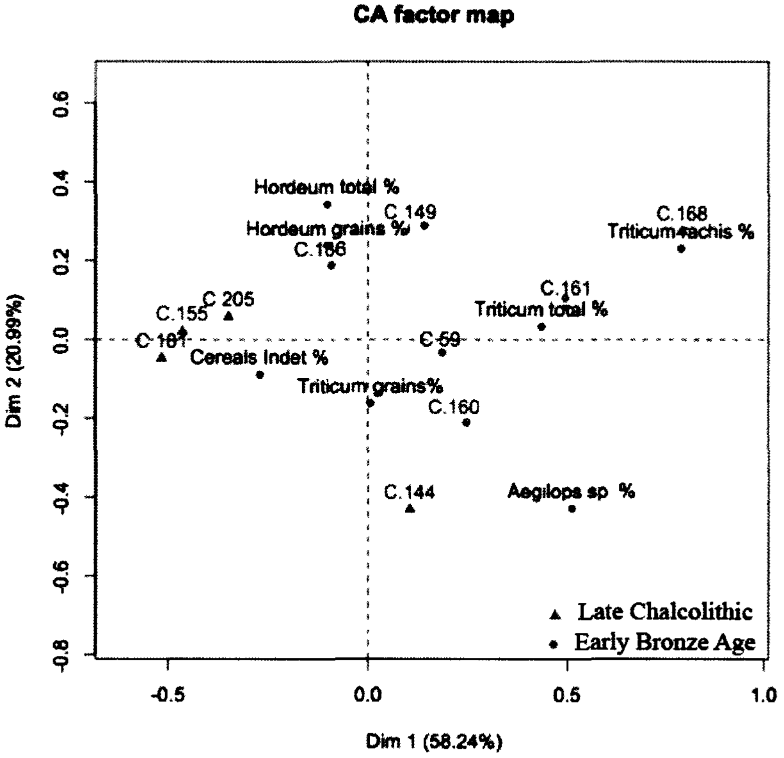

Figure 5.8 CA Plot based on percentage abundance values of *Triticum* sp. components (grains and rachis), *Hordeum* sp. components (grains and rachis), *Aegilops* spp, total scores for *Hordeum* sp. and *Triticum* sp, and cereals indeterminate.

This plot also displays the distinctive distribution of barley rachis, with a very high value on the negative side of axis 2. This situation is confirmed with the fact that barley rachis is represented in high quantities in samples C 149 and C 186, both period 2B samples. Referring to raw data counts (Appendix 1A), apart from C 149 and C 186, barley rachis is poorly represented in most of the samples: six out of the ten samples do not have any barley rachis, while the other two samples (apart from C 149 and C 186) with barley rachis have very low quantities. On the other hand, as mentioned earlier in section 5.2.1 (see also Table 5.5), barley grains are very common, and much more abundant than barley rachis. Therefore, the low ubiquity and abundance of barley rachis is compressing the rest of the cereal components, causing a slight clustering of most of the samples. In an effort to further analyze the patterning of cereal components an additional plot was drawn using the same dataset, this time excluding barley rachis (Figure 5.9).

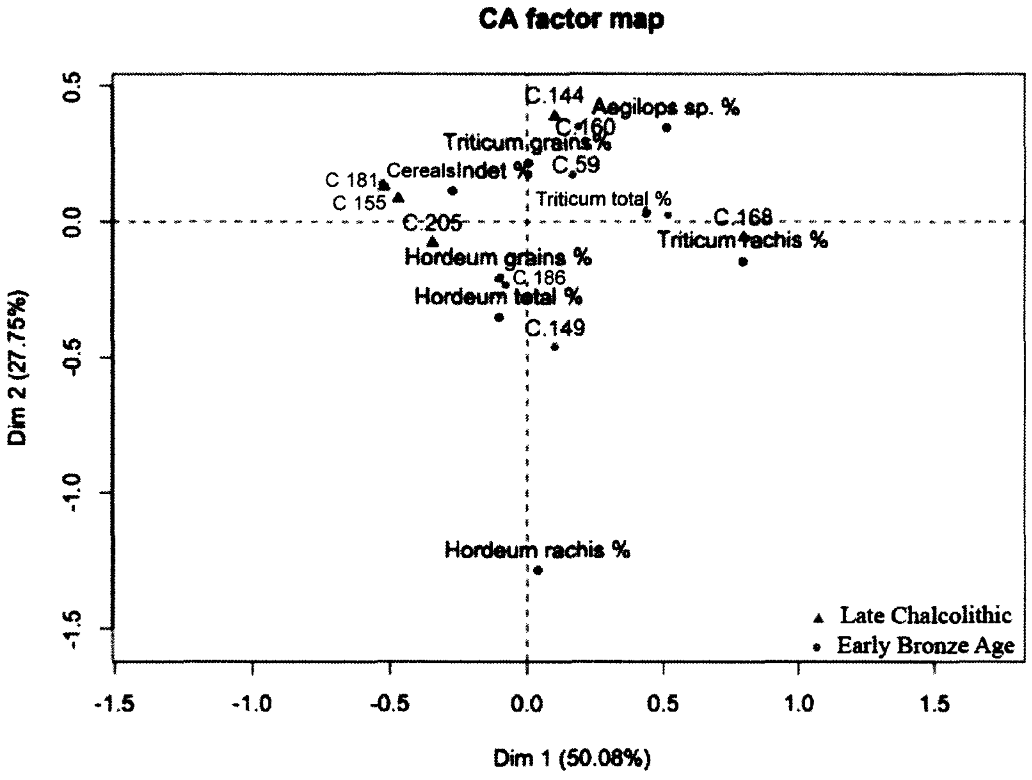

Figure 5.9 CA Plot based on percentage abundance values of *Triticum* sp. components (grains and rachis), *Hordeum* sp. components (grains, excluding rachis), and *Aegilops* spp, cereals indeterminate, and total scores for *Triticum* sp. and *Hordeum* sp.

In this plot (Figure 5.9), the separation along axis 1 (Dim 1), accounting for 58.2% of the variation in the patterning, indicates that wheat and barley elements are opposite each other. This suggests that a greater degree of variation in the composition of the cereal components of samples depend on the distribution of wheat and barley. On the other hand, the indeterminate cereals, along with wheat grains, are on the negative side of axis 2 (Dim 2, accounting for 21% of the variation), while total (rachis and grains) values for wheat and barley are on the positive side of this axis. *Aegilops* sp. (grains and rachis) is found on the positive side of both axes, opposite indeterminate cereals and wheat and barley total. It seems that goat grass only has a similar patterning to wheat grains, occurring in higher abundances when there are higher abundances of wheat grains in the samples (refer to Appendix 1A for raw counts).

In terms of sample distributions, six samples (the three from 2A, and the two from period 1B and C 149 from period 2A) are on the positive side of axis 1, while four samples (all 3 from period 1A and C 186 from period 2A) are on the negative side of this axis. This division reflects partially the distributions of wheat and barley (with the exception of C 149). As discussed earlier in the chapter (see Section 5.2.1, Figure 5.4), five samples have higher abundances of wheat than barley and these are all of the period 2A and period 1B samples, which in this plot are on the same side of the axis 1 as wheat components and goat grass. On the other hand, all samples from period 1A and period 2B have higher abundances of barley than wheat, and four of these are on the same side of axis 1 as barley components and indeterminate cereals. The exception to this patterning is sample C 149, a sample that has a very high concentration of barley elements, the highest raw counts of wheat spikelet fragments and the highest raw counts of indeterminate cereal culm nodes (refer to Appendix 1A). The CA plot in Figure 5.9 indicates that the strongest separation between most samples (nine out of ten) can be attributed to total counts of barley elements and wheat elements, and the correlation between these two crop categories is negative.

As discussed in Section 5.2, numerical analyses of cereal crop proportions reveal uneven distributions of grain and rachis/spikelet fragments for both hulled barley and hulled wheat. Statistical analyses, as discussed above, suggest that a greater degree of patterning across time periods can be explained by combining grain and crop processing waste elements that can be identified to the species level. Therefore, both numerical and statistical analysis suggest that during periods 1A and 2B, hulled barley was more prevalent in the archaeobotanical record, whereas hulled wheat was more prevalent during periods 1B and 2A.

5.3.2 Weed Ecology

To interpret the ecological significance of taxa presence in these samples CA was run on data based on presence/absence counts from 22 samples from Jerablus Tahtani. As a statistical technique CA allows for the analysis of patterning in data based on presence/absence, and have been used in ecological studies (see Gauch 1982 for a detailed discussion), and in archaeobotanical studies (Bogaard 2004: 92-95). Presence/absence scores of taxa present in at least 1% of the overall sample abundance were included for the wild/weedy taxa identified to genus level and species level from Jerablus. The reason for this reduction in data size was to overcome the shortcomings of archaeobotanical data, as most often extremely rare taxa cause redundancies in analyses. It is noted by several authors that archaeobotanical data tends to reflect the uncertainty of taphonomic and site formation processes whereby taxa composition and distribution varies across contexts causing noise in the quantified data (Riehl 1999: 21, Colledge

2001: 67). Similar approaches in data reduction have been successfully implemented in order to overcome the skewing of data patterning caused by extremely rare taxa present in very low abundances. Gauch (1982: 7) notes that ecological data tends to have several points of redundancy and noise due to the fact that often times data collected from identical ecological conditions do not produce identical sample compositions. To add to this situation, archaeobotanical data reflects even more discrepancies related to context types, exposure to fire, and mixing of stratigraphic layers. The main ecological attribute tested was the flowering period of wild/weedy taxa in order to ascertain whether there is a significant trend in terms of time period indicating shifting agricultural and field management systems. As mentioned in Chapter 4, the dominant presence of late flowering weedy taxa has been interpreted by some scholars to be an indication of irrigation systems in areas where annual rainfall tends to be low (Charles et al. 2003).

In order to standardize flowering period, May was taken as an arbitrary time for the evaluation of late vs. early flowering periods due to the fact that in the region most fields where dry farming is practiced harvesting period would be May/June, therefore the likelihood of later flowering taxa to survive would be less (see for a detailed account Charles and Hoppé 2003). Similar approaches have been implemented by other authors in assessing weed ecologies (Charles et al. 2003, Charles and Hoppe 2003, Jones et al. 2010). A list of wild/weedy taxa selected for analysis and their respective flowering periods can be seen in Table 5.7 (sources for flowering period: *Flora of Turkey and the East Aegean Islands,* Davis 1965-1985, and *Flora Palaestina,* Zohary 1966, 1987, Feinbrun-Dotham 1978, 1986).

Taxa	Taxon codes	Flowering Period
Adonis sp.	ADONSPE	E
Aegilops spp.	AEGISPE	L
Ajuga/Teucrium spp.	AJUGTEU	L
Androsace maxima	ANDRMAX	E
Arnebia decumbens	ARNEDEC	E
Astragalus spp.	ASTRSPE	E
Avena spp.	AVENSPE	E
Bromus spp.	BROMSPE	L
Buglossoides incrassata	BUGLINC	L
Buglossoides tenuiflora	BUGLTEN	E
Chenopodium spp.	CHENSPE	L
Coronilla spp.	COROSPE	L
Eremopyrum spp.	EREMSPE	E
Galium spp.	GALISPE	E
Glaucium spp.	GLAUSPE	L
Heliotropium europeum	HELOEUR	L
Hordeum spontaneum	HORDSPO	E
Hyoscyamus spp.	HYOSSPE	L
Lolium spp.	LOLISPE	L
Malva spp.	MALVSPE	E
Medicago spp.	MEDISPE	E
Polygonum spp.	POLYSPE	L
Prosopis farcta	PROSFAR	L
Rumex spp.	RUMESPE	L
Scirpus spp.	SCIRSPE	L
Sherardia arvensis	SHERARV	L
Silene spp.	SILESPE	E
Thymelaea spp.	THYMSPE	L
Vaccaria pyrimidata	VACCPYR	L
Valerianella dentata	VALEDEN	L
	Total Early Flowering: 12; Total Late Flowering: 18	

Table 5. 7 Flowering periods of taxa and taxon codes included in the CA plot (E=Early Flowering, L=Late Flowering)

The results of the CA plot run on incidence data based on the given criteria can be seen in Figure 5.10. Upon initial examination, the plot reflects a marked redundancy in sample composition due to an overarching similarity in the occurrences of certain weed/wild taxa. This situation is reflected in the clustering of several samples and a great majority of the taxa near the origin (where axes 1 and 2 coincide), indicating that whatever patterning there might be in the samples are being obstructed by the presence of extremely rare taxa in samples C 186 and C 19. In order to overcome this situation, and the low percentage of cumulative variation (25%) explained by the first two dimensions, several approaches were taken to understand the complexity of the data.

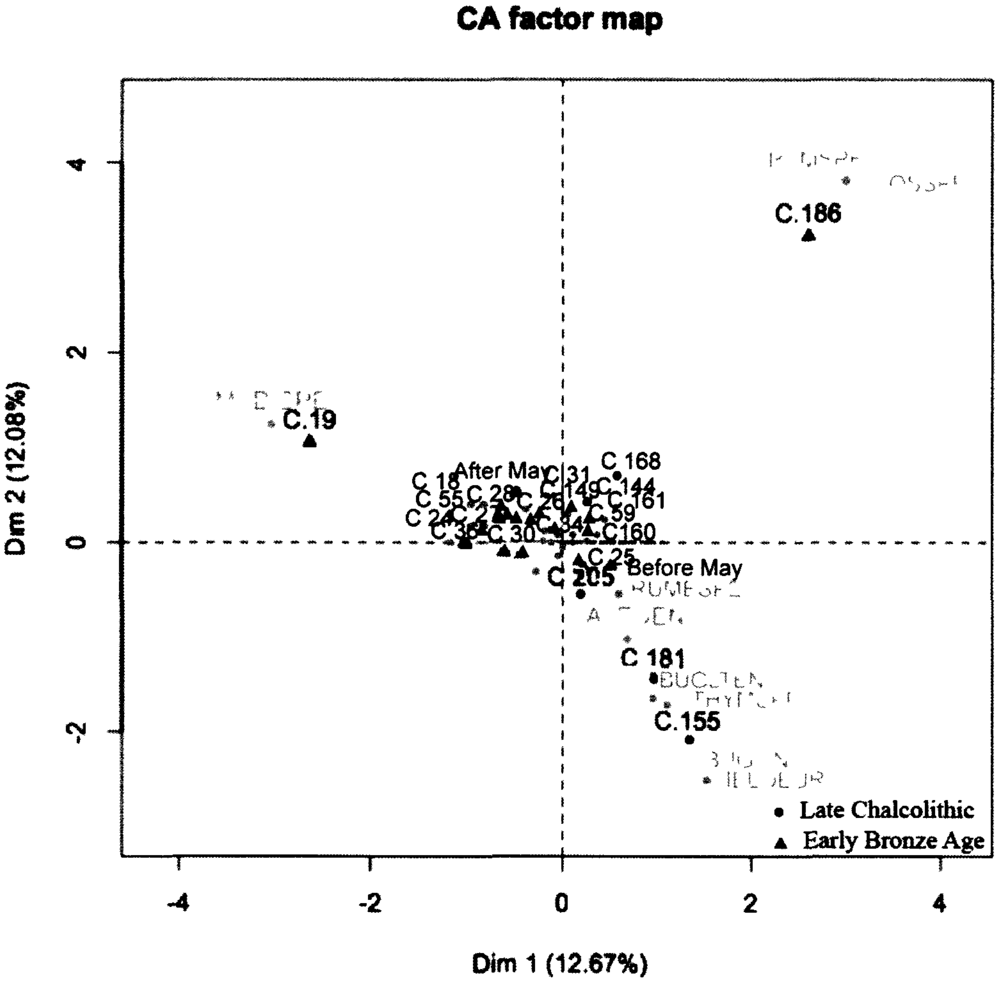

Figure 5.10 CA plot of presence/absence data from all Jerablus samples of wild/weedy taxa (due to the tight clustering of taxa in the center of the plot these taxon labels are not displayed in the plot)

Additional analyses were run on presence/absence data excluding the scores for sample C 186, and C 19 (Figure 5.10). The resulting plot, accounting for a cumulative variance of 30% in two axes, displays that a greater variance occurs on axis 1 (Dim 1), where samples in the early Late Chalcolithic (Period 1A) have a more common occurrence of late flowering species (C 155, C 181, C 205). In addition, samples C 160 and C 59, period 2A samples are on the same side of axis 1 as period 1A samples, opposite a great majority of samples from period 2B, including Tomb 302 contexts (with the exception of sample C 25).

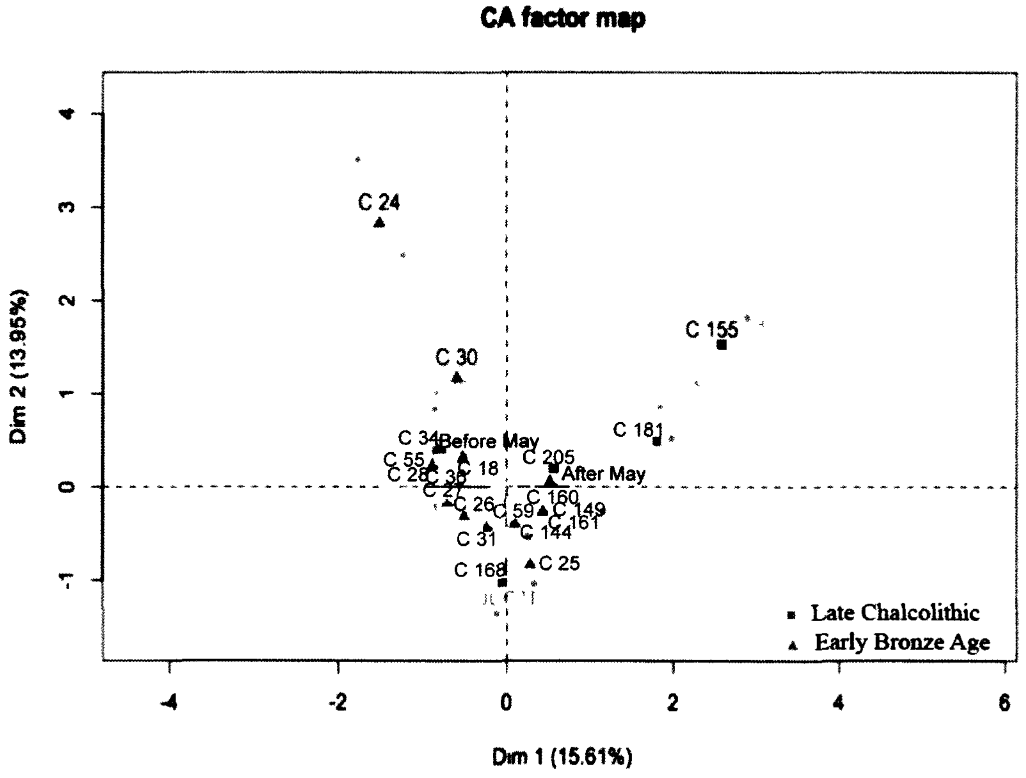

Figure 5.11 CA plot of presence/absence data from all Jerablus samples excluding C 186 and C 19, incidence data of wild/weedy taxa (due to the tight clustering of taxa in the center of the plot these taxon labels are not displayed in the plot)

As can be seen from the above plot (Figure 5.11), there is still a degree of skewing in the patterning, where a great majority of the samples and taxa are clustered around the origin (the intersection of axes 1 and 2) due to the presence of rare species such as *Eremopyrum* sp., and *Hyoscyamus* sp. present only in sample C 186, *Silene* sp. present in only sample C 24, and *Medicago* sp. present only in sample C 19. Therefore, any patterning in the distribution of early flowering vs. late flowering taxa is being obscured. In order to evaluate the patterning more thoroughly, the mentioned species (*Silene* sp., *Eremopyrum* sp., *Hyoscyamus* sp., and *Medicago* sp.) were excluded from the CA plot in Figure 5.12 (see below).

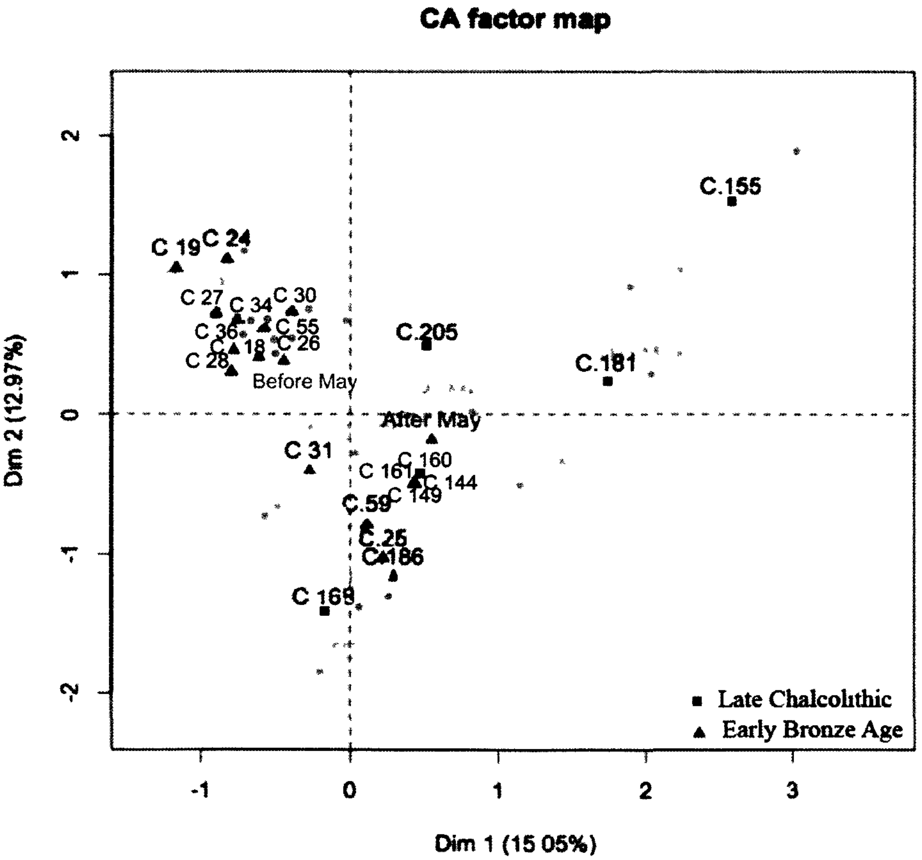

Figure 5.12 CA plot of presence/absence data from all Jerablus samples of wild/weedy taxa, excluding Silene sp., Eremopyrum sp., Hyoscyamus sp., Medicago

sp. (due to the tight clustering of taxa in the upper left quadrant of the plot these taxon labels are not displayed in the plot)

The CA plot in Figure 5.12 shows a clear separation between the ten samples analyzed for this study and a majority of the T 302 samples. With the exception of C 31 and C 25, all T 302 samples are on the opposite side of the axes in relation to the ten samples coming from other contexts. Another clear signature is the separation of period 1A samples (C 155, C 181, C 205) from the rest of the 22 samples, similar to the situation in the CA plot in Figure 5.8. In addition, the T 302 samples have more common occurrences of early flowering wild/weedy taxa, while the ten samples analyzed for this study have more commonly late flowering taxa.

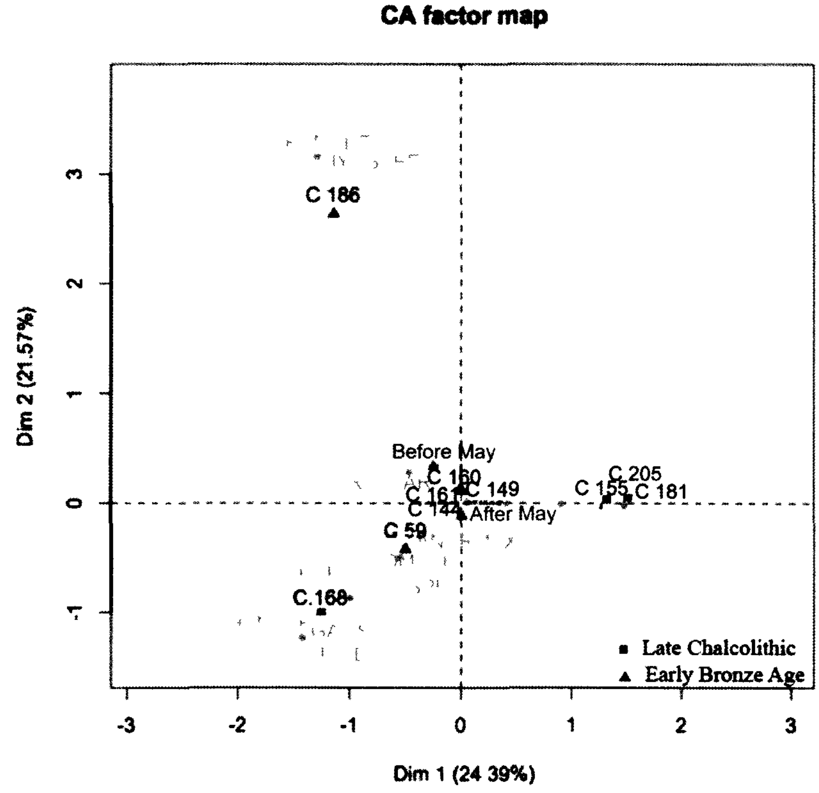

Figure 5.13 CA plot of presence/absence data from ten Jerablus samples of wild/weedy taxa (due to the tight clustering of taxa in the center of the plot these taxon labels are not displayed in the plot)

Further analyses were carried on the ten samples analyzed for this study (Figure 5.13). The resulting plot displays a similar trend as seen in Figure 5.10, where most of the samples cluster around the intersection of the two axes, indicating a skewing in the patterning due to rare species. Therefore, further analyses were run excluding species *Eremopyrum* sp., *Hyoscyamus* sp. (Figure 5.14).

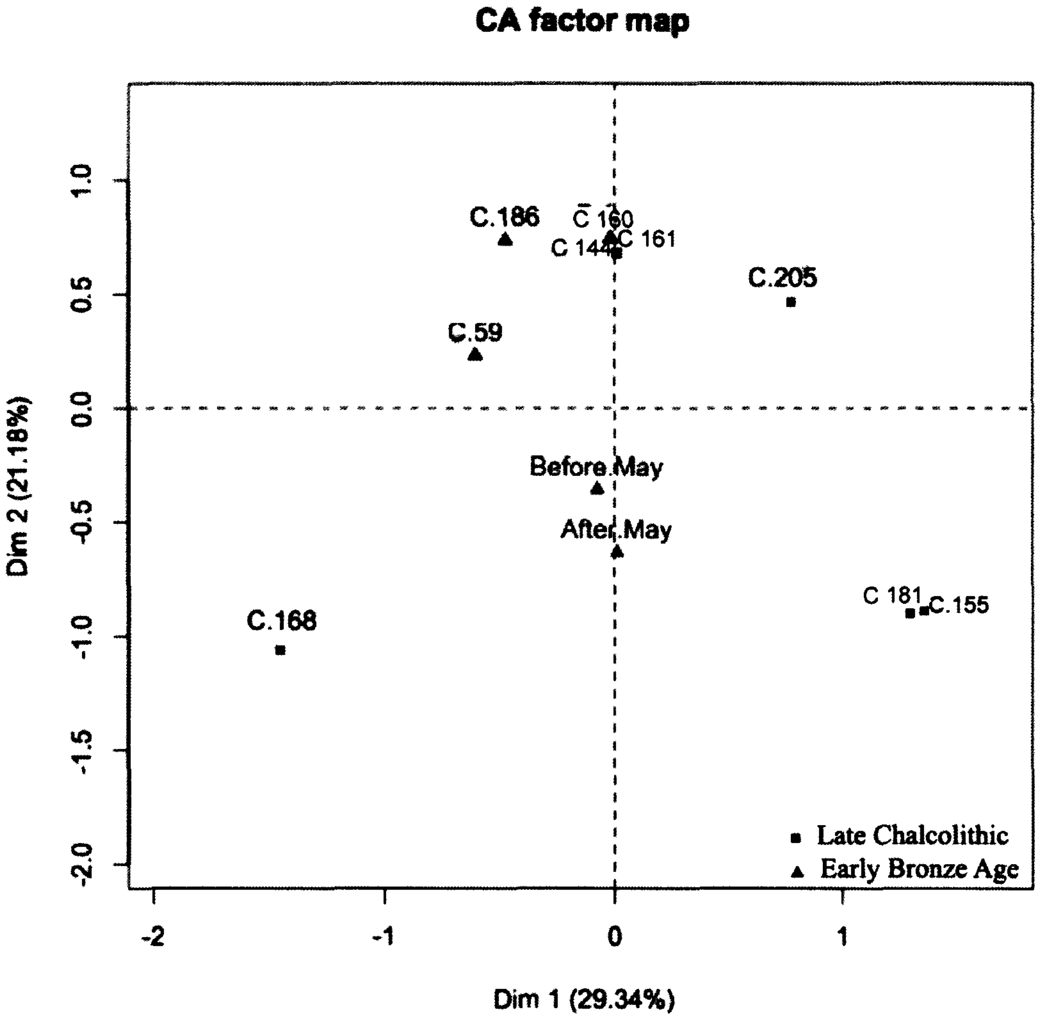

Figure 5.14 CA plot of presence/absence data from ten Jerablus samples of wild/weedy taxa, excluding *Eremopyrum* sp., *Hyoscyamus* sp.

Figure 5.14 displays a separation across axis 1 accounting for 29% of the variation between period 1A samples (C 181, C 155, and C 205) and the rest of the ten samples included in the plot. In the patterning, early flowering vs. late flowering does not seem to hold a much defined separation. Rather, the changing ecological signature over time could be more related to the range of habitats represented. However, testing such attributes (i.e. steppe, fields, fallow fields, rocky hills etc.) would require a finer degree of identification since most of the wild/weedy taxa could only be identified to genus level.

Overall, the ten samples analyzed for this study samples reflect a higher emphasis on late flowering taxa than the T 302 samples. However, when the total number of late flowering vs. early flowering weed taxa are tabulated for each sample from T 302 and the ten samples analyzed for the current study, in all but seven samples there are more late flowering taxa than early flowering taxa (Table 5.8).

Time period	Sample	Number of early flowering taxa	Number of late flowering taxa
Late Chalcolithic	C 155	1	3
	C 205	2	3
	C 181	1	3
	C 168	1	5
	C 144	0	3
Early Bronze Age	C 59	1	6
	C 161	0	3
	C 160	0	3
	C 186	1	2
	C 149	0	3
	C 55	4	2
	C 25	1	6
	C 28	6	4
	C 24	1	2
	C 31	1	3
	C 34	2	1
	C 30	1	3
	C 36	1	0
	C 18	1	0
	C 19	2	0
	C 27	3	2
	C 26	1	2

Table 5.8 Summary of number of taxa or early flowering and late flowering wild/weedy t

The seven samples with higher numbers of early flowering weed taxa are all samples taken from Tomb 302, dating to the Early Bronze Age. In general, the wild/weedy taxa composition of T 302 samples seems to indicate that these samples have a different archaeobotanical signature than the other Jerablus samples. This distribution could be related to two variables: ecological shifts related to time period (i.e. change between Early Bronze Age and Late Chalcolithic) or contextual differences (i.e. specialized context in and around the tomb mound and general occupational debris). If the distribution is related to time periods, it would be expected to see Late Chalcolithic samples to stand out in CA plots of wild/weed taxa. As discussed earlier in this subsection, when the distribution is not skewed by individual samples and/or rare taxa, the plots indicate that there is a distinct separation between Late Chalcolithic and Early Bronze Age samples (Figures 5.12, 5.14). It is therefore possible that there is an ecological shift being represented through time at Jerablus. Whether this is caused by environmental conditions (progressively drying conditions towards the end of the Early Bronze Age) or by shifts in subsistence strategies (i.e. irrigation farming) is not clear. It could be argued that due to the overarching dominance of late flowering taxa during the Late Chalcolithic and the Early Bronze Age signals to the existence of the use of irrigation despite differences in the specific early/late flowering taxa between the time periods. However it is important to remember that most of the samples analyzed from Jerablus contain charred dung fragments, indicating that some of these wild/weedy taxa would have been remains of livestock feed/fodder. Whether or not there was a water management system tied to agriculture is not clear, however, there is an indication that ecological signatures are changing across time. On the other hand, the overarching presence of late flowering taxa across time periods suggests that spring sowing regimes were in practice, despite the frequent spring flooding of the Euphrates River.

Additionally, these plots indicate that T 302 samples have different sample compositions compared to samples coming from general domestic/occupational debris at the tell (see Figure 5.12). This differentiation could be linked with either different depositional processes or different formation processes linked to the contexts. For instance, since Tomb 302 is located in Area II---a separate area of the site than Areas III and IV, where the ten samples analyzed for this study come from (see map, Figure 2.3 in Chapter 2). It could be the case that Area II which is much closer to the Euphrates riverbank than Areas III and IV, could be more susceptible to spring flooding, resulting in the deposition of higher amounts of plant matter early in the spring compared to the other areas of the tell. It is noted in preliminary excavation reports that this section of the tell was particularly prone to flooding and that the spring floods at times reached over the fortification walls. However, such an interpretation would be highly speculative since the number of samples analyzed and studied is very few. Alternatively, the taxa compositions of Tomb 302 samples could be related to depositional practices. If for instance there was a lower likelihood of charred dung fragments being incorporated into a specialized context such as a tomb (for any given reason, not excluding cultural preferences) than we could argue that the resulting differences on wild/weed taxa composition is directly linked to the absence of dung and dung derived plant matter. As mentioned earlier, only one sample from the T 302 context contains a small amount of dung fragments, where as a majority of the samples coming from the rest of the site (8 out of 10) contain dung fragments. However, fully testing such an interpretation is difficult considering the poor preservation of dung fragments coming from the site.

5.4 Summary of Results

The botanical data analyzed from Jerablus Tahtani, representing a range of contexts, reflects a relatively low charred material density (see table 5.1), with low species richness and uneven distribution of abundances. The ten samples analyzed as part of this research were also compared to data available from the Early Bronze Age tomb complex T 302.

The results suggest that, in general, crops are the most abundant taxa category with cereals being the most ubiquitous and abundant. Indeterminate cereal grains, those that lack enough identifiable morphological traits, comprise the main portion of cereals, while hulled wheat and hulled barley are the most predominant cereal crops. In general, there are more barley grains than wheat grains, while there is more wheat spikelet fragments than barley rachis. Overall, however, there seems to be broadly similar representations of barley and wheat. The cereal crops reflect a great degree of fragmentation, either as a result of food/crop processing, or through site formation processes.

Legumes and pulses are less ubiquitous and also less abundant, with lentil being the most common. The only fruit crop identified is grape, with a low ubiquity, and high abundance in only one sample (C 59). Wild and weedy taxa have much lower proportions in terms of abundance, although this category accounts for a majority of the taxa diversity in samples. The most ubiquitous wild taxa are small seeded legumes and goat grass. Most of the wild/weedy taxa identified from Jerablus have flowering periods that extend after May, indicating later harvesting times in the fields and spring sowing, and perhaps arable weed species of irrigated fields. There is a separation of time periods (Late Chalcolithic and Early Bronze Age), in addition to distinct archaeobotanical signatures of sample compositions from Tomb 302.

In Chapter 6 the implications of these results will be discussed taking into account changes in environmental and climatic conditions, and socio-political shifts that might reflect in modes of food production and agriculture.

Chapter 6. Discussion

The site-specific and regional implications of the results presented in Chapter 5 will be discussed in this chapter also drawing on the background literature provided in Chapter 2 with regards to the urban economy, environmental and climatic conditions, and socio-cultural change at Jerablus Tahtani.

6.1 Crops

6.1.1 Crop Use at Jerablus Tahtani

Even though the dataset analyzed from Jerablus Tahtani is limited, and does not represent all areas of excavation, it is possible to make some limited inferences on crop choices and processing methods at the site. Judging from the samples examined, cereal crops, especially hulled barley and hulled wheat, are very important. There is also some indication of the relative importance of lentils through previous reports on the existence of lentil storage areas (Murray 1995), even though the relative abundance of this species was very low in flotation samples. The T 302 contexts have also produced some evidence of pulses/legumes such as *Lens* sp. (lentil), *Vicia/Lathyrus* (vetch/pea) type and *Cicer* sp. (chickpea) (Colledge and Stevens forthcoming).

It has been noted in previous reports (Murray 1995:24-25, 1996: 20-21) that by abundance and ubiquity, barley is the dominant crop. A closer examination of results from this study suggests that there is in fact a slight dominance of hulled barley grains in most samples compared to hulled wheat grains, however when rachis and chaff counts are taken into consideration, the situation appears to be more complex (Chapter 5, Table 5.5 and Figure 5.4). A likely source of the uneven distribution of barley and wheat grains could be the modes of processing that each crop goes through prior to consumption. During this time period in the Near East, a high abundance of wheat rachis along with high amounts of barley grain are interpreted by some authors to be evidence of fodder (Charles 1998). In addition, it is important to note that, within the ten samples analyzed, higher abundance of wheat grains compared to barley grains coincides with higher fragmentation in the cereal assemblages. The relatively low abundances of hulled barley rachis in samples could also indicate that perhaps this crop was brought onto the site after processing, or was preferentially stored in cleaned form, whereas wheat was kept in uncleaned form. From Jerablus Tahtani, there are reports of well cleaned, "relatively pure sample[s] of barley" storage contexts from earlier preliminary analyses (Peltenburg *et al.* 1995:5). However to date, there are no reports of large scale whole wheat grain storage contexts from Jerablus. Future work on the morphological traits of processed grains, resulting in fragmentary preservation of cereals, could shed light on the importance each crop (barley and wheat) has in the early urban agriculture in the Near East.

There is very limited evidence for the presence of flax at Jerablus, an important textile crop. In addition, some preserved wood charcoal fragments from these taxa reported from Jerablus suggest that grape and olive crop trees were kept or managed within close vicinity of the site (Deckers and Pessin 2010). However, seed macroremain analyses at Jerablus have provided very little evidence of cultivated grape seeds and olive stones.

6.1.2 Crop use in the Near East during the Late Chalcolithic and Early Bronze Age

The Jerablus crop assemblage seems to confirm the trends of a high frequency of hulled wheat, hulled barley, and lentils reported from a variety of Early Bronze Age sites across northern Syria and southeastern Turkey (Hald 2010, Smith 2005: 267). In an evaluation of regional data on botanical remains from sites across the Near East dating to the Bronze Age period, Riehl (2009) concludes that over time through the end of the Early Bronze Age and during the Middle Bronze Age there is a shift in agricultural systems placing greater emphasis on drought resistant crops, such as barley. At Tell Brak, the earlier (Middle/Late Chalcolithic samples tend to show a greater abundance of wheat, while the later Early Bronze Age samples display a dominance of barley grains (Colledge 2003).

Within the broader Near Eastern context, it is also argued that there is a greater emphasis placed on barley, especially in southern Mesopotamia, due to agricultural intensification and environmental stress (Riehl 2009). However in order to draw conclusions on the importance of either crop in the Near East during the 5th-4th millennia, further analyses into food processing technology, and the potential use of ground/processed cereal crops are necessary. In fact, most archaeobotanical reports dating to the Bronze Age and Late Chalcolithic in the Near East tend to omit the fragmentary indeterminate cereals in interpretation, and instead focus on identifiable whole grains and their respective proportions in addition to rachis and chaff elements.

Flax as a textile crop plays an important role in the understanding the dynamics of crop use and agriculture in the Near East during the Late Chalcolithic and Early Bronze Age. McCorriston (1997) suggests that the decline in the presence of flax indicates a shift towards use of wool for textiles instead of linen through the end of the Late Chalcolithic and beginning of Early Bronze Age in the region (McCorriston 1997). It is difficult to ascertain whether the relative low frequency of flax at Jerablus is indicative of a stronger emphasis on specialized wool textile production. In contrast, findings from contemporaneous Tell Brak indicate the presence of flax as an important part of the crop assemblage, recovered in situ storage (Hald and Charles 2008).

Interestingly, preliminary faunal analyses on Jerablus Tahtani material suggest the presence of higher proportions of sheep remains compared to goat in assemblages (Peltenburg et al. 1995:24). A similar trend is reported in southern Mesopotamia at approximately 4000 BC, where wool textile production is associated with higher number of wool bearing sheep compared to goats (McCorriston 1997). Without further knowledge on the breed of sheep found at Jerablus and more faunal samples analyzed, it would be hasty to speculate on the potential for wool production at the site even though there is some evidence of textile production with findings of clay discs and bobbins during excavations (Peltenburg et al. 1997:7).

Lentil is reported widely across the region, along with chickpeas, vetch, and pea, however in much lower quantities compared to cereal grains. Some authors also suggest that the low abundances of lentils and other legumes/pulses in botanical assemblages could be due to the fact that they are not preferred as a source of livestock feed, thus not appearing in botanical assemblages as part of animal dung (Miller 1997). It has also been argued that due to processing techniques and their high oil content legumes and pulses are less likely to be preserved in the archaeobotanical record (Gustaffson 2000).

6.2 Wild/Weedy Taxa

Numerical analyses on taxa diversity, as reported in Chapter 5, suggest that during the Early Bronze Age flotation samples are richer in the composition of wild/weedy taxa, with higher Shannon indices for samples from this time period and a greater range of different taxa.

6.2.1 Fodder and Livestock Feed

It is very likely that animal dung was used as fuel at Jerablus Tahtani. Previous reports indicate the presence of charred dung from various contexts in Jerablus (Murray 1995, 1996, Colledge and Stevens forthcoming). Dung is a valued source of fuel in the region today due to its better burning qualities and ease of collection and storage (Charles, Halstead, and Jones 1998). Crop processing debris, such as wheat chaff and barley rachis, was probably used as fodder, in addition to barley grain (McCorriston and Weisberg 2002). Ethnographic studies carried out on dung fuel use and livestock feed suggest that various crops such as wheat, barley, rye, oats, and vetch and wild/weedy plants are used in animal feed (Anderson and Ertug 1998). A closer analysis of dung contents from this ethnographic study reveal that rachis and culm fragments of cereals and wild/weedy taxa dominate the composition of dung samples, while several leguminous feed sources such as vetch and pea were poorly preserved (Anderson and Ertug 1998: 103). These findings agree with the compositions of Jerablus botanical samples.

The importance of plant material sourced from dung has not been overtly expressed in reports of Jerablus Tahtani material; however, certain contexts provide useful clues to the evaluation of plant material derived from animal feed. As mentioned in Chapter 5, sample C 168, contains a higher abundance of charred dung compared to the other samples and also has a high diversity of wild/weedy taxa in addition to a more pronounced abundance of chaff fragments, both indicative of possible animal feed surviving in dung cakes as outlined in ethnoarchaeological studies (Anderson and Ertug 1998). It is highly likely that a portion of the seed macroremains from Jerablus Tahtani represent dung inclusions.

6.2.2 Weed Ecology

As part of statistical analyses in assessing the productivity of fields in relation to soil moisture content, CA was run on 22 samples from Jerablus Tahtani. Statistical analyses of weed ecology data based on the presence of late flowering taxa suggests that a spring sowing period was in practice, despite the high risk associated with spring flooding in fields around the site. It is suggested by some authors that the presence of greater proportions of late flowering taxa could also suggest water management in agricultural fields, or low-level irrigation (Jones 2002). In order to test such a shift more data from the site is necessary. In addition, as mentioned in Chapter 5, the weed flora reflects a diversification during the Early Bronze Age, especially with the higher presence of early flowering taxa compared to Late Chalcolithic deposits. This situation could be suggesting that more than one season of planting was being practiced, intensifying the use of agricultural fields. It is important to note that interpretations at this stage are limited with sample numbers and especially with the higher number of samples analyzed from the Early Bronze Age.

As mentioned in Chapter 2 Jerablus Tahtani lies in the suitable rainfall zone (400-300 mm/year) for dry farming. Therefore in times of optimum environmental conditions it would not have been necessary to implement an irrigation system, unless higher land productivity was desired. Irrigated systems in southern Mesopotamia during the Early Bronze Age were common due to the low annual rainfall in this region (200 mm/year Wilkinson 2007). It is also noted by some authors that during periods of drought, such as the 4.2 KBP drought period, annual rainfall in northern Syria could have declined below 200 mm/year, reducing agricultural yields significantly (Riehl 2009). Therefore it is possible that the inhabitants of Jerablus Tahtani would have developed strategies to overcome extensive drought periods with low-level irrigation. Analyses of botanical data from Tell Brak display a similar proportion of late flowering and early flowering weed taxa (Hald and Charles 2008). However, as mentioned earlier, further evidence is necessary to better assess the presence of water management systems in agricultural fields near Jerablus.

6.3 Climatic/Environmental Change at Jerablus Tahtani

As summarized in Chapter 2, there are various changes in environmental and climatic conditions through the last part of the Chalcolithic and the Early Bronze Age. In general, the environmental conditions in the Middle Euphrates valley seem to reflect moister conditions during the Late Chalcolithic and earlier part of Early Bronze Age, leading to an abrupt drying event at the end of the Bronze Age (ca. 2200 BC) (Kuzucuoğlu 2007). At the same time, during the later part of 3rd millennium BC the Euphrates River takes on a more volatile course, and the sites in close vicinity of the river bank would have been susceptible to seasonal flooding (Wilkinson 2007).

Jerablus Tahtani was settled ca. mid-4th millennium BC on the actively aggrading

Euphrates floodplain, in close proximity of the riverbank and the site was flooded routinely from the earliest levels of occupation (Peltenburg 2007a, Peltenburg et al. 1997). It is noted that there was an episode of mega-flooding that reached as high as 11 meters towards the end of Period 1 in Jerablus chronology, coinciding with the mid-3rd millennium BC (Peltenburg 2007a: 256). Radiocarbon dates from the latest phases of the Early Bronze Age fortification at the site indicate that the abandonment of the tell took place ca. 2300/2200 BC (Peltenburg 2007a).

In light of environmental and climatic shifts it seems likely that crop production would have been under stress due to periodical floods, unless fields for cultivation were kept at a different locale further inland of the site. Such a situation would have allowed for the maintenance of the agricultural economy during periods of Euphrates flooding, but the Early Bronze Age drought might have made the crop production more vulnerable as a result of being further away from a major water source at times of low annual rainfall.

As mentioned in Chapter 2, charcoal studies in the region confirm a relatively wet environment during the Early Bronze Age, and taxa reported from Jerablus Tahtani indicates a varied riverine forest in the vicinity of the tell. The high proportions of *Salix/Populus* compared to *Tamarix* has been interpreted as favorable river flooding in the area for the growth of wet loving trees while there is a remarkably lower proportion of taxa of steppic woodland (i.e. *Quercus*) (Deckers and Pessin 2010). The charcoal evidence at Jerablus, along with weed ecology evidence seems to point out to relatively moist conditions right before the onset of the abrupt climate change at the end of the Early Bronze Age.

6.4 Urban Economy at Jerablus Tahtani

As outlined in Chapter 2 the late Chalcolithic and Early Bronze Age in the Near East represents two cycles of urban development, with increasing socio-political complexity across the region. In Jerablus, from the establishment of the site, to the hiatus at the end of the Early Bronze Age, there is clear evidence of a rising elite group, political affiliations with neighboring urban centers, craft specialization, and high levels of trading activity with sites across the Euphrates Valley. All of these developments would require production of a surplus, at least an increase in agricultural yields. Therefore, in discussing the urban economy at Jerablus Tahtani, it is important to revisit the concepts of extensification and intensification. Both concepts originate from modern agricultural economics (Boserup 1965) and comparatively define the nature of agricultural production with regards to an increase in yield.

In either scenario, the amount of land under cultivation is taken as a variable in direct negative relation to all the other resources necessary for agricultural production (i.e. labor, fertilizers, technology, and animal labor). Extensification is defined as a case in which a greater area is planted using fewer resources through either less human labor investment (i.e. the use of animal traction), or less capital investment (i.e. abandoning fertilizer/manure use on the fields). Intensification on the other hand refers to a situation where arable land is stable or diminishing, however production outputs are kept at the same level or even increased through the use of more labor, new technologies that are time consuming, or the increasing use of soil quality improving strategies (tilling, manuring, fertilizing, etc.). In other words, intensification is increasing the output per unit of land through greater productive input per unit, whereas extensification is increasing output by expanding production without increasing.

More speculatively, there are clear socio-political shifts taking place at the site with the appearance of an elite class and craft specialists that would suggest the need for increasing agricultural production in order to be able to provide enough food to these groups at Jerablus that did not take part in farming and/or crop processing. In fact evidence of increased and specialized food production comes from the appearance of storage facilities dating to the Early Bronze at the site along with associated communal crop processing and food preparation areas.

The use of livestock for labor (i.e. transportation, food processing, plough) along with dairying and wool production signals a new period in early agricultural economies where a range of storable products and labor without slaughtering of the animals. Limited evidence of these events exist at Jerablus and without further, more detailed, studies of faunal remains at the site it is very difficult to assess the likelihood of pastoral activity at the site. There have not been reports of plough/ard findings at the site, or any relics representing cattle-driven plough. However the remains of domesticated donkey were reported in a preliminary analysis of faunal remains and is a possible indication of this animal being used for transportation (Peltenburg et al. 1995:5).

At Jerablus the evidence for shifting economic structures to support an urban population comes from the appearance of food processing and metal working areas during the Early Bronze Age (Peltenburg et al. 1997, 2000). The highest number of quern stones are found in Early Bronze Age layers, especially during the earlier part of Early Bronze Age (period 2A) (Peltenburg 2007a), the samples analyzed for this study dating to the 2A period suggest the presence of higher abundances of wheat dating to this time period, along with greater fragmentation of cereal remains. In addition, Peltenburg (2007a) suggests that this cereal processing activity would have been focused in one area of the site (Area IV), suggesting the centralization of food processing. Further evidence is necessary from more samples across the site in order to assess the extent of food processing specialization. In addition, further research into distinguishing pre-deposition fragmentation (as a result of food processing) and post-deposition fragmentation could prove useful in assessing the relative importance of crop species and whether crops were preferentially stored in a later phase of the production sequence.

There are also various caches of mass produced ceramic wares dating to the Late Chalcolithic and Early Bronze Age (Peltenburg et al.1995). The data on craft specialization from Jerablus seems to suggest the development of specialized production. For instance, the presence of crucibles for metal smelting, gold sheets, and copper alloy mixed with color pigment suggests fine metalworking in the form of jewelry making could have been present, indicating the specialized production of elite during the Early Bronze Age (Peltenburg et al. 1997: 5). Further metalworking evidence comes from moulds for metal weaponry making and crucibles dating to the Early Bronze Age (Peltenburg et al. 2000:61).

It is clear that there is some conglomeration of labor during the Early Bronze Age with contexts such as B 1000 (Building 1000, Peltenburg et al. 1996:9) providing evidence for increasing deposits of grinding stones over time (Peltenburg 2007a). The caches of bevel-rim bowls, recently suggested to be used as bread baking moulds (Goulder 2009), dating to the Late Chalcolithic at Jerablus can be taken as further evidence of the scale of food processing activities.

As discussed earlier, the clear importance of cereal crops is evident in the assemblage, with the most prominent crop taxa being hulled varieties of wheat and barley. Both hulled wheat and hulled barley tend to have superior drought tolerance, and do not require high soil fertility for successful yield (Riehl in press). As the weed ecology studies indicate, it is possible that there were some measures taken in increasing the yield of these crops, as suggested by shifting wild/weedy taxa composition across time periods. However, in order to assess whether such measures were the result of intensification or extensification strategies more data from Jerablus is necessary. On the whole, there seems to be some indication for intensification at the site, especially if weed ecology data is taken to suggest the presence of multiple seasons of cropping and irrigation and further analyses can test the validity of these patterns.

6.5 Summary

The botanical assemblage at Jerablus is dominated by crop taxa, hulled barley and hulled wheat, while pulses appear in much lower frequency. It is likely that taphonomic factors such as food processing, fire temperatures and patterns of deposition play an important role in the abundances represented. Taphonomic processes are also indicated by the very low charred material densities, comparable to other contemporaneous sites from the region such as Tell Brak (Colledge 2003) and Tell es-Sweyhat (Miller 1997). There is very little evidence for tree cultivation, coming mostly from low frequency charcoal specimens of olive and vine. Dung, along with wood from nearby riverine forests, was used for fuel, and it is likely that livestock feed and inclusions in dung represent a portion of the taxa identified. The weed ecology and abundances of wood charcoal represent, in general, a wet environment throughout the Late Chalcolithic and Early Bronze Age. High representation of riverine forest species (*Salix/Populus*) and very low representation of oak woodland forests indicate a prominent wetland environment, suggesting that there could have been woodland clearance during the Late Chalcolithic and Early Bronze Age inland from the riverbank, where fields could have been located. At this stage there seems some support for the potential of intensification at the site, although further studies in the identification of food processing techniques, especially in relation to cereal grinding could prove useful in answering questions with regards to intensification of labor and crop choices. It is likely that legume/pulse crops would have been farmed along the riverbank using annual flooding, while cereal crops could have been kept on higher terraces (Cooper 2006: 30).

The economy at Jerablus was based on a mixed agropastoral subsistence system, with a high likelihood of riverine trading and possible overland trading from major political centers on the eastern bank of the Euphrates (such as Ebla) with those on the west bank. Various trade items, and on site production of metal objects included in elite burials suggest the appearance of a local class differentiation, with important ties to nearby centers such as Carchemish. It is likely that this economic system, which thrived during the Early Bronze Age, could have become unsustainable or unprofitable and dispersed, rather than a collapse, by the end of the period, coinciding with a sudden drying phase ca. 2200 BC.

Chapter 7. Conclusions

The main aim of this thesis is to add to the existing body of ecofactual data in relation to the ways in which early complex societies interact with the environment, and more specifically how the changing climatic patterns reflect onto agricultural production in contexts where there is evidence of increasing political complexity. In order to develop our understanding of the dynamics of the evolving agropastoral economy in the Near East, botanical macroremain analysis was carried out on ten samples dating to the Late Chalcolithic and Early Bronze Age periods from Jerablus Tahtani. The samples dating to the Late Chalcolithic and Early Bronze Age were sorted and analyzed in detail at Trent University. With evidence provided through excavations directed by Dr. Edgar Peltenburg (1992-1999) the site provides a very good case study for examining the effects of climatic and environmental change, in addition to socio-political shifts.

As discussed in Chapter 2, Jerablus is located on the east bank of the Euphrates River, in northern Syria about 10-km south of the present Turkish border (Figure 2.1). The four-hectare tell displays early signs of developing socio-political complexity during the Early Bronze Age while the settlement size expands with labour intensive construction efforts (fortification walls, and tombs such as T 302) and indications for monumental architecture. In addition, the geopolitically strategic location of the settlement with access to north-south trade routes along the Euphrates made this site a preferable trade route as evidenced by the wide range of ceramic and glyptic styles in addition to various imported raw materials and goods from across Mesopotamia and southeastern Anatolia (McCarthy 2007, Peltenburg *et al.* 2000

A summary of climatic/environmental and socio-cultural history of the Middle

Euphrates Valley can also be found in Chapter 2 (Table 2.1). The paleoecological proxy data from various sources across the Near East indicates that the climatic conditions were generally drier in the second half of the Holocene, with some regions (such as Lake Van multi-proxy data) reflecting drying phases later than others due to their northern latitudes (Wick et all 2003). On the other hand, most of the climatic proxies from the region indicate an abrupt drying event around 4.2 kya (Kuzucuoğlu 2007). In addition, during the Early Bronze Age, in the Euphrates River valleys there were several episodes of extreme flooding, also documented in Jerablus, making autumn sown crops susceptible to failure (Peltenburg 2007a).

Along with changing socio-political and environmental dynamics in the region, 4th-3rd millennium BC in the Near East reflect an increasing importance of agropastoral production in order to support growing urban populations, while craft specialization, especially in the manufacture of elite commodities and metalworking, thrived (Akkermans and Schwartz 2003). At the end of the Early Bronze Age, coinciding with the 4.2 kya drying event, several settlements along the northern sectors of the Euphrates River were abandoned (Jerablus Tahtani, Tell Banat, Al-Rawda), while several others in close vicinity experienced an urban sprawl (Carchemish, Tell Brak, Tell Mozan). Debates on the explanation of this period at the end of the Early Bronze Age have previously focused on an urban collapse, with some authors suggesting that settlements grew beyond the limits of sustainability and the socio-political systems collapsed (Algaze 2005). At the same time, the possibility of dispersal and resettlement with new political affiliations also seems likely and are supported with recent evidence (see collective volume Kuzucuoğlu and Marro 2007, Peltenburg 2007a).

In order to answer the research questions outlined in Chapter 1, detailed analyses were carried out on the macroremain samples from Jerablus. Most of the samples were chosen from Area III and IV identified by Peltenburg et al. (2000) as a section of the settlement that is transformed during the Early Bronze Age with much higher population densities during this time period and possibly a crop processing and/or food production installment in Area IV. The systematic quantification and the evaluation of taxa representation based on raw counts, proportion percentages, ubiquity, and incidence, as outlined in the methods section in Chapter 4, allowed for a better understanding of assemblage composition.

While evaluating the macroremain botanical evidence at Jerablus, Correspondence Analysis was used to evaluate changes in proportions of various crop taxa and wild/weedy taxa over time and across various contexts. CA, as outlined in Chapter 4, is a method successfully applied to archaeobotanical and ecological data in previous studies, and is used as an analytical tool that allows for the evaluation of complex trends in datasets (Gauch 1982). In addition, questions regarding ecological conditions were evaluated using wild/weedy taxa present at the site. As outlined in Chapter 4, ecological conditions reflected by the range of wild taxa can be indicative of field management strategies, sowing season, or in general environmental conditions around the site, and to this end data on the flowering periods of weedy taxa present in samples at Jerablus were compiled from the published floras in the region (*Flora of Turkey and the East Aegean Islands,* Davis 1965-1985, and *Flora Palaestina,* Zohary 1966, 1987, Feinbrun-Dotham 1978, 1986).

As outlined in Chapter 5, the results of macroremain analysis show that cereal crops dominate the botanical assemblages by abundance and ubiquity, while legumes/pulses represent much lower percentages. It is likely that a portion of the taxa identified represent inclusions in dung, and livestock feed, as dung was likely used for fuel at the site. Correspondence Analysis on the wild/weedy taxa composition of the ten samples processed at Trent University and the samples from Tomb 302 reflect that samples vary in composition across contexts with the Tomb 302 samples reflecting greater proportions of early flowering taxa compared to general occupation deposits. Overall, most samples reflect greater proportions of late flowering taxa. The general profile of wild/weedy taxa in the samples suggest possible spring sowing. In terms of crop agriculture, there seems no overarching dominance of hulled barley over hulled wheat, as generally suggested for the 3rd millennium BC in the Near East (see Figure 5.2, Table 5.5) (Riehl 2009).

In fact, the results of analyses indicate that there is a variety of crop processing stages reflected in the assemblages with the general dominance of wheat chaff over barley chaff, and a dominance of barley grain over wheat grain (Figure 5.2). However, as discussed in Chapter 3, taphonomic variables affecting archaeobotanical assemblages have to be evaluated carefully. The composition of the samples reflect a low abundance of wild/weedy taxa, with a majority of these taxa coming from wild grasses (such as goat grass) that have seeds in similar sizes and density to cereal crop grains (Table 5.4). In most cases, cereals compose more than half of the overall sample abundance (Table 5.4). It should be noted that an overarching amount of these are fragmentary indeterminate cereals (Table 5.5). In this case, as discussed in Chapter 5 and 6 with regards to the results of abundance and ubiquity measures, it seems likely that a majority of the crop taxa represented come from household waste reflecting various stages of food preparation. The few instances where higher abundances of wild/weedy taxa are present, these are usually accompanied by charred dung fragments, most likely indicating that a variety of small seeds consumed by livestock and preserved in the dung were charred as a result of use of dung for fuel.

As outlined in Chapter 6, the environmental interpretation of present weed taxa and wood charcoal indicates the presence of riverine woodland nearby, with several wet-loving plant species present that would have allowed for the hunting of various bird species, and other wetland animals. It is possible that nearby riverine environments were used as follow fields, taking advantage of the annual flooding. Since parts of the ancient flood plain were preserved around Jerablus, Wilkinson (2007) argues that Jerablus would have had an advantageous location in the region with regards to access to the size of cultivable land (see Figure 2.2). The degree to which these fields were under threat of destructive spring flooding is not clear, however the enduring volatile environmental conditions have urged prehistoric and historic agropastoral populations in the region to develop various strategies in ensuring a steady supply of crops. It is likely that the inhabitants of Jerablus either kept additional fields away from the river floodplain or practiced a mixed sowing season strategy. It is possible that the shifting weed flora during the Early Bronze Age suggests more than one season of planting and harvest, or the more intensive use of fallow fields.

The desirable location of the site on the Euphrates riverbank either facilitated riverine trade, or served as an important post on overland trade networks connecting the east bank of the Euphrates with the west bank. Therefore the increasing socio-cultural complexity and a thriving urban population during the early Bronze Age would have been supported through the trading systems and surplus production on site. At this stage, site abandonment looks to be a dispersal of the urban population towards other centers in the region, fueled by environmental and political change.

Future Research and the Limitations of the Current Study

Further studies on the botanical assemblage at Jerablus in conjunction with detailed faunal analyses would provide more insights into the full urban economy at Jerablus. It is noteworthy to mention that there have been reports of possible looting at Jerablus, especially of the T 302 complex (Peltenburg et al. 1997), indicating further complexities in analyzing ecofactual remains from the site. In addition, site disturbances through various phases of flooding, during and after the occupation of the site, make it difficult to give a detailed view of the deposition processes. It is generally accepted that in botanical assemblages the full spectrum of plant material used or carried to the site are not represented, rather only a limited view of plant use can be inferred. However, a better understanding of plant use can be achieved with additional data on starch residues and micromorphology, evaluated in conjunction with plant macroremain analysis, especially in understanding the methods of food processing.

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APPENDIX A.1 Raw data counts of samples analyzed from Jerablus Tahtani

Sample No		C 155	C 205	C 181	C 168	C 144	C 59	C 161	C 160	C 186	C 149
Area		III	III	III	III	III	III	III	III	IV	IV S2
Unit		2194	2610	2482	2393	2012	976	2319	2307	2387	2059
Period		1A	1A	1A	1B	1B	2A	2A	2A	2B	2B
Flot Volume (ml)		21	10.8	3.5	44	32.5	24.5	15	16.25	29.75	37
Volume Floated (l)		200	35	35	35	200	40	25	25	35	100
Density of charred material (ml/l)		0.11	0.31	0.10	1.26	0.16	0.61	0.6	0.65	0.85	0.37
Total #ID Items		794	353	163	2328	975	144	495	728	1124	1107
Items/lt		4	10	5	67	5	4	20	29	32	11
Shannon Index		1.8	2.0	1.7	1.7	2.1	2.2	2.4	2.1	2.5	2.7
CEREALS											
Hordeum cf. spontaneum	grains	-	4	-	-	-	-	-	3	2	4
Hordeum spontaneum/vulgare	rachis	-	7	-	-	-	-	-	-	39	67
Hordeum vulgare	grains	45	17	10	9	25	-	23	9	56	77
	indet frags	33	25	5	13	37	9	45.3	17	52	84
	rachis	-	-	-	-	-	-	3	-	4	16
	basal rachis	-	-	-	-	-	-	-	-	-	1
Triticum boeoticum /secale	grains	-	-	-	-	-	-	1	-	-	-
Triticum monococcum	grains	-	-	-	1	-	-	2	-	-	-
	indet frags	-	-	-	3	-	-	11	-	-	-
Triticum cf. monococcum	grains	6	1	-	-	1	-	4	-	2	1
	indet frags	-	1	-	-	-	-	-	-	-	-
Triticum dicoccum	grains	-	-	1	1	1	-	-	-	-	-
Triticum cf. mono/dicoccum	grains	3	3	2	-	9	1	3	6	13	21
	indet frags	33	9	4	2	59	11	13	17	17	22
	spkt fks	-	3	-	35	5	1	21	27	9	13
	glume bases	-	-	-	59	28	2	67	57	61	93

Sample No		C 155	C 205	C 181	C 168	C 144	C 59	C 161	C 160	C 186	C 149
Triticum spp. (free-threshing)	grains	6	-	-	1	2	-	1	-	-	-
	rachis	-	-	-	1	-	-	-	-	-	-
Cereals indeterminate	grains	14	6	1	3	13	1	1	18	31	17
	indet frgs	407	182	94	94	430	21	156	349	442	358
	culm nodes	-	-	-	-	-	-	-	3	1	46
	basal rachis	-	-	-	1	-	-	-	-	-	-
LEGUMES/PULSES											
Vicia ervilia		1	-	-	-	-	-	-	-	-	3
Lens sp.		-	-	-	2	2	0.5	2	-	8	4
Vicia/Pisum spp.		-	-	-	-	-	-	-	-	2	4
Vicia/Lathyrus spp.		-	-	-	-	2	-	-	1	6	2
Large legumes indeterminate		1	1	-	-	2	-	10	-	15	14
GRASSES											
Aegilops spp.	grains	-	8	1	3	39	5	11	21	10	24
	indet frags	-	6	1	18	50	2.5	53	28	8	21
	spikelet fks	-	2	-	5	67	-	9	16	8	40
	glume bases	-	1	-	8	25	-	8	20	3	-
Bromus spp.		-	1	-	12	3	3	-	2	7	9
Hordeum spp. - weed types		-	-	-	1	-	-	-	-	-	-
Lolium spp.		-	1	-	11	2	1	1	-	2	-
Phalaris spp.		-	-	-	1	-	-	3	-	-	-
Eremopyrum spp.		-	-	-	-	-	-	-	3	35	6
Setaria/Panicum cf.		-	-	-	1	-	-	-	-	-	-
Stipa spp.		-	-	-	-	-	-	-	-	1	-
Paoaceae	indet grains	-	-	-	3	-	-	-	1	1	1
OTHER WILD TAXA											
Chenopodium sp.		-	-	-	92	-	-	-	-	-	4
Carthamus sp.		-	-	-	1	-	1	-	-	-	-
Arnebia decumbens		-	2	1	2	-	-	-	-	6	-
Boraginaceae Uncharred		112	29	17	7	16	1	-	6	76	27

Sample No	C 155	C 205	C 181	C 168	C 144	C 59	C 161	C 160	C 186	C 149
Buglossoides incrassata	47	3	1	2	-	-	-	5	-	-
Buglossoides tenuiflora	25	10	4	19	2	1	1	-	9	5
Heliotropium cf. europeum.	23	-	-	2	-	-	-	-	-	-
Brassica/Sinapis cf.	-	-	-	4	-	-	-	-	-	-
Cannabis cf.	-	1	-	-	-	-	-	-	-	-
Capparis sp.	-	-	-	1	-	-	-	-	-	-
Minuartia/Arenaria sp.	-	-	-	-	-	-	1	3	9	8
Silene/Gysophilia sp.	-	-	-	5	-	-	-	-	-	-
Vaccaria sp.	-	-	-	2	-	-	-	1	-	-
Compositae indeterminate (small)	18	-	-	8	-	-	-	-	-	1
Scirpus sp.	-	-	-	91	-	5	-	-	-	-
Astragalus sp.	-	-	-	-	-	-	-	-	-	-
Coronilla sp.	-	7	-	13	1	1	-	-	7	10
Leguminosae small	7	18	12	1493	138	15	35	95	133	68
Medicago radiata	-	-	-	3	-	-	-	-	-	-
Medicago sp.	-	-	-	-	-	-	-	-	-	-
Prosopis cf. farcta	-	-	-	3	-	-	-	-	1	3
Erodium sp.	-	-	-	-	-	-	-	3	-	-
Ajuga/Teucrium sp.	2	-	1	132	-	1	-	-	-	-
Labiatae spp.	-	-	-	2	-	-	-	-	2	-
Ziziphora sp.	-	-	-	-	-	-	1	-	-	-
Liliaceae indeterminate	-	-	-	-	-	-	1	-	-	-
Linum sp.	1	-	-	1	10	1	3	1	1	1
Malva sp.	-	-	-	3	1	1	-	-	-	-
Ficus sp.	-	-	-	-	-	-	1	-	-	-
Olea sp.	-	-	-	-	-	-	-	-	2	-
Fumaria sp.	-	1	-	-	-	-	-	-	1	5
Plantago cf.	-	-	-	2	-	-	-	-	-	-
Polygonum corregiloides	-	-	-	3	-	-	-	1	-	-
Polygonum spp.	-	1	-	6	-	-	-	7	5	8

Sample No	C 155	C 205	C 181	C 168	C 144	C 59	C 161	C 160	C 186	C 149
Rumex spp. (small)	-	-	-	-	1	-	-	-	-	-
Androsace cf. maxima	4	-	-	8	-	3	1	-	-	4
Adonis sp.	-	-	-	1	2	-	1	1	6	3
Galium sp. (small)	1	2	-	123	2	-	2	6	6	4
Hyoscyamus sp.	-	-	-	-	-	-	-	-	17	4
Thymelaea sp.	4	-	4	1	-	-	-	-	-	-
Umbelliferae indeterminate (small)	-	1	-	1	-	-	-	-	4	-
Valerianella cf. dentata	1	-	4	9	-	-	-	-	4	4
Vitis vinifera	-	-	-	-	-	55.5	-	1	-	-
rodent droppings	-	-	-	-	-	1	1	-	-	8
large indeterminate	3	-	-	-	-	-	4	-	-	2
small indeterminate	-	-	-	12	2	-	14	2	6	21
Dung (gr)	1.015	0.583	0	9.791	0.111	0	0.218	0.081	0.246	0.737

APPENDIX A.2 Weed ecology incidence data

Sample Number	C 155	C 205	C 181	C 168	C 144	C 59
Adonis sp.	0	0	0	0	0	0
Aegilops spp.	0	1	0	0	1	1
Ajuga/Teucrium sp.	0	0	0	1	0	0
Androsace cf. *maxima*	0	0	0	0	0	1
Arnebia decumbens	0	0	0	0	0	0
Astragalus sp.	0	0	0	0	0	0
Avena sp.	0	0	0	0	0	0
Bromus spp.	0	0	0	0	0	1
Buglossoides incrassata	1	0	0	0	0	0
Buglossoides tenuiflora	1	1	1	0	0	0
Chenopodium sp.	0	0	0	1	0	0
Coronilla sp.	0	1	0	0	0	0
Eremopyrum spp.	0	0	0	0	0	0
Galium sp.	0	0	0	1	0	0
Glaucium sp.	0	0	0	0	0	0
Hordeum cf. *spontaneum*	0	1	0	0	0	0
Heliotropium cf. *europeum*	1	0	0	0	0	0
Hyoscyamus	0	0	0	0	0	0
Lolium spp.	0	0	0	0	0	0
Malva sp.	0	0	0	0	0	0
Medicago sp.	0	0	0	0	0	0
Polygonum spp.	0	0	0	1	0	1
Prosopis cf. *farcta*	0	0	0	1	1	1
Rumex spp.	1	1	1	0	1	1
Scirpus sp.	0	0	0	1	0	1
Sherardia arvensis	0	0	0	0	0	0
Silene sp.	0	0	0	0	0	0
Thymelaea sp.	0	0	1	0	0	0
Vaccaria pyrimidata	0	0	0	0	0	0
Valerianella cf. *dentata*	0	0	1	0	0	0

Table A. 2 Weed ecology incidence data.

Sample Number	C 161	C 160	C 186	C 149	C 55	C 25	C 28
Adonis sp.	0	0	0	0	0	0	1
Aegilops spp.	1	1	0	1	1	1	1
Ajuga/Teucrium sp.	0	0	0	0	0	0	0
Androsace cf. *maxima*	0	0	0	0	0	0	0
Arnebia decumbens	0	0	0	0	1	0	0
Astragalus sp.	0	0	0	0	1	0	1
Avena sp.	0	0	0	0	1	0	1
Bromus spp.	0	0	0	0	0	0	1
Buglossoides incrassata	0	0	0	0	0	0	0
Buglossoides tenuiflora	0	0	0	0	0	0	0
Chenopodium sp.	0	0	0	0	0	0	1
Coronilla sp.	0	0	0	0	1	0	0
Eremopyrum spp.	0	0	1	0	0	0	0
Galium sp.	0	0	0	0	0	0	1
Glaucium sp.	0	0	0	0	0	0	0
Hordeum cf. *spontaneum*	0	0	0	0	1	1	1
Heliotropium cf. *europeum*	0	0	0	0	0	0	0
Hyoscyamus	0	0	1	0	0	0	0
Lolium spp.	0	0	0	0	0	0	1
Malva sp.	0	0	0	0	0	0	1
Medicago sp.	0	0	0	0	0	0	0
Polygonum spp.	0	0	0	0	0	1	0
Prosopis cf. *farcta*	1	1	1	1	0	0	0
Rumex spp.	1	1	0	1	0	0	0
Scirpus sp.	0	0	0	0	0	1	0
Sherardia arvensis	0	0	0	0	0	1	0
Silene sp.	0	0	0	0	0	0	0
Thymelaea sp.	0	0	0	0	0	0	0
Vaccaria pyrimidata	0	0	0	0	0	1	0
Valerianella cf. *dentata*	0	0	0	0	0	1	0

Table A. 2 Weed ecology incidence data, *continued.*

Sample Number	C 31	C 34	C 30	C 36	C 18	C 27	C 26	C 24
Adonis sp.	0	0	0	0	0	0	0	0
Aegilops spp.	1	0	0	0	0	0	1	0
Ajuga/Teucrium sp.	0	0	0	0	0	0	0	0
Androsace cf. *maxima*	0	0	0	0	0	0	0	0
Arnebia decumbens	0	0	0	0	0	0	1	0
Astragalus sp.	0	0	0	0	0	0	0	0
Avena sp.	1	1	1	0	0	1	0	0
Bromus spp.	0	1	1	0	0	1	0	1
Buglossoides incrassata	0	0	0	0	0	0	0	0
Buglossoides tenuiflora	0	0	0	0	0	0	0	0
Chenopodium sp.	1	0	0	0	0	0	0	0
Coronilla sp.	0	0	0	0	0	0	0	0
Eremopyrum spp.	0	0	0	0	0	0	0	0
Galium sp.	0	0	0	0	0	0	0	0
Glaucium sp.	0	0	1	0	0	0	0	1
Hordeum cf. *spontaneum*	0	1	0	1	1	1	0	0
Heliotropium cf. *europeum*	0	0	0	0	0	0	0	0
Hyoscyamus	0	0	0	0	0	0	0	0
Lolium spp.	0	0	0	0	0	1	1	0
Malva sp.	0	0	0	0	0	1	0	0
Medicago sp.	0	0	0	0	0	0	0	0
Polygonum spp.	0	0	0	0	0	0	0	0
Prosopis cf. *farcta*	1	0	0	0	0	0	0	0
Rumex spp.	0	0	1	0	0	0	0	0
Scirpus sp.	0	0	0	0	0	0	0	0
Sherardia arvensis	0	0	0	0	0	0	0	0
Silene sp.	0	0	0	0	0	0	0	1
Thymelaea sp.	0	0	0	0	0	0	0	0
Vaccaria pyrimidata	0	0	0	0	0	0	0	0
Valerianella cf. *dentata*	0	0	0	0	0	0	0	0

Table A. 2 Weed ecology incidence data, *continued*.