

# Journal of Archaeological Science: Reports

## A stable isotope and functional weed ecology investigation into Chalcolithic cultivation practices in Central Anatolia: Çatalhöyük, Çamlıbel Tarlası and Kuruçay --Manuscript Draft--

Manuscript Number:	JASREP-D-20-00427R2
Article Type:	Research Paper
Keywords:	Stable carbon and nitrogen isotopes; Crop husbandry; Chalcolithic; anatolia; Functional weed ecology
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Abstract:	<p>The integration of stable isotope analysis of crop remains with the ecological analysis of archaeological weed flora allows for a detailed reconstruction of crop husbandry and arable growing conditions. This paper presents the first such study for Chalcolithic Central Anatolia, exploring the differences in crop husbandry at the large (8 ha) Early Chalcolithic site of Çatalhöyük West and contemporaneous last phases of Çatalhöyük East, and the small Late Chalcolithic sites of Çamlıbel Tarlası (0.025 ha) and Kuruçay (~1 ha). The results reveal the mosaic nature of Çatalhöyük cultivation; the complex ecosystem, naturally <math>^{15}\text{N}</math> enriched, was additionally anthropogenically improved, while inhabitants also chose to cultivate barley in drier conditions to the other crops. The smaller site of Çamlıbel Tarlası instead cultivated each individual crop species in variable conditions instead of selecting a specific species for cultivation in drier or wetter conditions. Each single species was cultivated in conditions with a wide range of water availabilities while receiving low-level manure application. This is possibly a consequence of the variable topography surrounding the site, with the hills potentially used for cultivation, providing a wide range of conditions due to their slope. Functional weed ecology complements the isotopic data, indicating the wider range of cultivation intensities surrounding Çatalhöyük West, compared with more consistent, narrower ranges of growing conditions at Çamlıbel Tarlası and Kuruçay. Site size and environment seem to be key contributing factors shaping the method used to cultivate crops at these Chalcolithic sites. The larger community of Çatalhöyük West, located in a complex riverine ecosystem around the dryland anabranching channels of the Çarşamba river, cultivated species in different conditions, maintained a range of crop husbandry intensities, potentially reflecting the differential access to limited resources. The smaller late Chalcolithic sites, with communities consisting of one household to several neighbourhoods and located in less complex ecosystems with higher precipitation, maintained more stable crop growing conditions and management intensities. This is possibly a consequence of equal access and sharing of critical resources for crop cultivation, such as labour, manure and land, coupled with the adequate precipitation rates.</p>
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**Title:** A stable isotope and functional weed ecology investigation into Chalcolithic cultivation practices in Central Anatolia: Çatalhöyük, Çamlıbel Tarlası and Kuruçay

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## Abstract

The integration of stable isotope analysis of crop remains with the ecological analysis of archaeological weed flora allows for a detailed reconstruction of crop husbandry and arable growing conditions. This paper presents the first such study for developed Neolithic and Chalcolithic Central Anatolia, exploring crop husbandry at the large (8 ha) early 6<sup>th</sup> millennium BC site of Çatalhöyük West and the last phases of the preceding Neolithic Çatalhöyük East, located on the western end of the Konya Plain, and the small 4<sup>th</sup> millennium sites of Çamlıbel Tarlası (0.25 ha), located in the loop of the Kızılırmak river, and Kuruçay Höyük (~1 ha), located on the shore of Lake Burdur. The results reveal the mosaic nature of Çatalhöyük cultivation; the complex ecosystem, naturally <sup>15</sup>N enriched, was additionally anthropogenically improved, while inhabitants also chose to cultivate barley in drier conditions to the wheats and pulses. The smaller, Late Chalcolithic site of Çamlıbel Tarlası cultivated each individual crop species in variable conditions instead of selecting a specific species for cultivation in drier or wetter conditions. Each single species was cultivated in conditions with a wide range of water availabilities while receiving low-level manure application. Variation in water availability is possibly a consequence of the variable topography surrounding the site, with the hills potentially used for cultivation, providing a wide range of conditions due to their slope. Functional weed ecology complements the isotopic data, indicating the wider range of cultivation intensities surrounding Çatalhöyük West, compared with more consistent, narrower ranges of growing conditions at Çamlıbel Tarlası and Kuruçay Höyük. Settlement date, site size and environment seem to be key contributing factors shaping the method used to cultivate crops at these Chalcolithic sites. The larger, earlier community of Çatalhöyük West, located in a complex riverine ecosystem around the dryland anabranching channels of the Çarşamba river, cultivated species in different conditions and maintained a range of crop husbandry intensities, potentially reflecting differential access to limited resources. The smaller Late Chalcolithic sites, with communities consisting of one household to several households and located in less complex ecosystems with higher precipitation, maintained more stable crop growing conditions and management intensities. This is plausibly a consequence of equal access and sharing of critical resources for crop cultivation, such as labour, manure and land, coupled with the adequate precipitation rates.

## 1. Introduction

Little is known about crop husbandry methods used on the Central Anatolia plateau during the so-called Chalcolithic, a 3000-year period book-ended by the richly researched Neolithic and the urban archaeology of the Bronze Age (Düring, 2011). Understanding the nature and diversity of crop production allows inferences regarding social relations and production strategies preceding the development of the highly stratified societies of the Early Bronze Age (Düring, 2011). For the first time the analysis of both crop stable isotopes and functional weed ecology from Chalcolithic sites in Central Anatolia are presented. The crop husbandry of the large Early Chalcolithic site of Çatalhöyük West and the last phases of its twin mound, Çatalhöyük East, are contrasted with that of the small Late Chalcolithic sites of Çamlıbel Tarlası and Kuruçay Höyük, shedding new light on crop husbandry methods in this poorly researched period.

This comparative study reveals how environmental setting and community size can influence the strategies used to cultivate crops. Recent research provides a suite of techniques – in particular, arable weed functional ecology, and stable carbon and nitrogen isotope analysis of crop remains – that complement each other, providing information regarding soil fertility, disturbance levels, manuring and water status, and the labour-intensity of crop cultivation. Botanical surveys and ecological characterisation of present-day arable fields under varying forms of ‘traditional’ management provide a framework with which to assess the nature of past cultivation environments, based on comparison of functional traits between modern and ancient crop weed floras (Bogaard et al., 2016; 2018). In particular, soil productivity and disturbance, inferred on the basis of weed functional traits, provide an index of labour inputs per unit area in the form of manuring, tillage, weeding etc. This is complemented by archaeological crop isotope data regarding both water availability, affecting stable carbon isotope ratios, and soil nitrogen composition through stable nitrogen isotope ratios, affected by the application of manure.

Crop husbandry methods during the Anatolian Chalcolithic have been investigated previously by Masi et al. (2014), with regard to Late Chalcolithic/Early Bronze Age water management strategies at Arslantepe, Eastern Turkey. Masi et al. (2014) found that high water requiring emmer was better watered (and hence potentially irrigated) than drought-tolerant barley, identified as rainfed on more marginal land. Other studies using Neolithic and Bronze Age samples to understand temporal trends in water availability also found similar patterns; wheat is generally seen as having a wetter signal (more negative  $\delta^{13}\text{C}$  values) than barley relative to

modern baselines (Riehl et al., 2014; Wallace et al. 2015). Other isotopic research on Anatolian Chalcolithic remains has primarily focused on understanding human and animal diets (Vaughan et al., 2013; Pickard et al., 2016; Makarewicz et al., 2017; Middleton, 2018). Research focusing on human and animal diets has included isotopic studies from Çamlıbel Tarlası and both mounds of Çatalhöyük (see Fig. 1 for location of sites).



Figure 1. A map of the locations of the archaeological sites mentioned within the text.

## 2. Background

### 2.1 Central Anatolian Chalcolithic

The Chalcolithic period on the Central Anatolia Plateau (Fig.1) is broadly defined as a temporal rather than a cultural phase. While this period is limited in research and excavated sites, it appears that the Early Chalcolithic (originally 6000 – 5500 cal. BCE according to Özdoğan and Başgelen (1999), now redefined as ca. 6000-5000 cal. BCE (Özdoğan, Başgelen, and Kuniholm 2012)) is a continuation of Neolithic traditions in terms of crop species used, animal husbandry, ceramic ware and shapes or cold-hammered copper use (Bogaard et al. 2017; Rosenstock et al. 2019). Any changes therein – the introduction of hulled barley for example – appear to have origins in the Late Neolithic, reaching fruition in the Early Chalcolithic. Changes do occur, however, with the development of painted pottery and changes to building form, with sites within the Konya plain and Lake District regions showing a shift to large, sometimes multi-story, rectilinear mudbrick structures with large

internal buttresses. At some sites this change appears to be a gradual development (e.g. Canhasan I), while at others there is more of an abrupt change (cf. Çatalhöyük East versus Çatalhöyük West). Site size ranges from Hacılar (~1.7ha) to Çatalhöyük and Canhasan I (~8ha) (Mellaart 1958; French 1962). Continuity in occupation from the Late Neolithic to Early Chalcolithic settlements occurs at some sites, highlighting the fact that the start of the Chalcolithic is arbitrarily defined in Central Anatolia as a temporal phase that starts at 6000 cal. BC, cutting through a cultural period centered around the Late Neolithic-Early Chalcolithic (Marciniak and Czerniak 2007; Özdöl-Kutlu et al. (2015); Anvari et al. 2017; Rosenstock et al. 2019).

The Middle Chalcolithic – circa 5000-4000 cal. BCE (Özdoğan, Başgelen, and Kuniholm 2012) is marked by the onset of extractive copper use defining the Chalcolithic in all neighbouring regions (Rosenstock, Scharl, and Schier 2016). This is an elusive period with a paucity of sites even in well-surveyed areas of the Lake District and the Konya plain (Baird, 2002; Vandam, 2015). The lack of sites during this period makes it difficult to trace links between the cultures of the Late Neolithic-Early Chalcolithic and the Late Chalcolithic period. The Late Chalcolithic, broadly covering the 4<sup>th</sup> millennium BC, is associated with distinctly different cultural remains to the Early Chalcolithic, including settlements with thin-walled rectilinear structures. Settlements range in size from Çamlıbel Tarlası (~0.25 ha) to larger sites such as Çadır Höyük (~4 ha) (Steadman et al. 2008).

## **2.2. Sites**

### **2.2.1 Çatalhöyük**

Çatalhöyük consists of twin mounds located on the Konya plain (Fig. 1). The large 12 ha Neolithic East Mound was excavated in the 1960s by Mellaart and from 1993 until 2017 by Ian Hodder and associated teams. Çatalhöyük East was occupied from c. 7100 until 5950 cal. BC (Bayliss et al., 2015; Marciniak et al., 2015). The material used in this study comes from both the East and West mounds. The Çatalhöyük East material is from the Team Poznań (TP) trenches, some of the youngest material found at Çatalhöyük East, dating from c. 6100 to 5950 cal. B.C. (levels TP Q-R) (Marciniak et al., 2015). The TP area involved the construction of multi-roomed dwelling structures of significant size with a centrally placed oven, but no built-in features or sub-floor burials, implying the emergence of more family-orientated independent structures that delineate ownership of external yards (Marciniak and Czerniak, 2007; Marciniak 2019).

159

160 The smaller 8 ha Early Chalcolithic Çatalhöyük West is located about 200m away from  
161 Çatalhöyük East. The material examined in this study comes from the Last and Gibson  
162 Trenches 1 and 2 as well as Trench 5 of the Biehl and Rosenstock excavations. Recent  
163 research suggests that initial occupation of Çatalhöyük West occurred during the final  
164 centuries of the Çatalhöyük East occupation, with West Mound settlement estimated to have  
165 commenced around 6100 cal. BCE (Orton et al., 2018). Mellaart divided the occupation of  
166 Çatalhöyük West into two phases – the Early Chalcolithic I (ECI) and Early Chalcolithic II  
167 (ECII) (Mellaart, 1965). All material from Trench 5 dates to the ECI (5900 – 5800 cal. BCE),  
168 while some remains from later Trench 1 pits fall within the ECII dating up to ca. 5500 cal.  
169 BCE (Orton et al., 2018).

170

171 Trench 5 excavations revealed eight mudbrick structures with large internal buttresses,  
172 hypothesized to have consisted of two stories and showing regional similarities with  
173 Canhasan I and Hacılar structures (French, 1998; Mellaart, 1970). The treatment of the  
174 houses upon abandonment highlights a shift away from the traditional classic Çatalhöyük  
175 East house closure practices. The Çatalhöyük West structures were neither burnt nor  
176 demolished, instead being infilled over time with refuse which built up in fine dumping  
177 layers (Anvari et al. 2017), another similarity to the Canhasan I buildings which were  
178 infilled with thin lenses of deposits containing the rubbish and refuse of the settlement  
179 (French, 1963, French 1966:115).

180

181 The present-day climate of the Konya Plain is classified as cold semi-arid/steppe and the site  
182 receives 350 mm of annual precipitation (de Meester, 1970). Geoarchaeological research has  
183 shown that a complex ecosystem surrounded the site: a mosaic of wet and dry areas created  
184 by a dryland anabranching channel system inside a wider arid region (Ayala et al., 2017).  
185 Coring indicates that one of the channels separated the two mounds and that during the  
186 occupation of Çatalhöyük West there was a localized wetter area to the south-east of the  
187 mound (Ayala et al., 2017). Anthracological and macrobotanical analyses indicate a mosaic  
188 of different vegetation surrounding the site (Kabukcu, 2017; Stroud, 2016; Stroud et al., in  
189 prep). Anthracological analysis identified riverine taxa as well as oak woodland vegetation,  
190 evidence of drier ecosystems (Kabukcu, 2017). Macrobotanical remains reinforce the  
191 presence of both wetland and arid aspects to the local landscape, with hydrophytic and  
192 halophytic species as well as typical steppe vegetation (Stroud 2016; Stroud et al., in prep).

193

194 Çatalhöyük West reveals continuities in agricultural resource use from Çatalhöyük East, with  
195 the continuation of sheep and goat herding including dairy use (Russell et al. 2013; Hendy et  
196 al. 2018; Rosenstock et al. 2019), and cultivation of glume wheats, free-threshing wheat and  
197 three dominant pulses (Bogaard et al., 2017; in press; Stroud, 2016; Stroud et al., in prep.).  
198 Domesticated sheep, goats and cattle increase in importance at Çatalhöyük West while hulled  
199 barley, an uncommon and late introduction at Çatalhöyük East, becomes the dominant barley  
200 form (Stroud 2016; Anvari et al., 2017; Bogaard et al., 2017; Stroud et al., in prep.). Stable  
201 carbon and nitrogen isotopic analysis of Çatalhöyük East and West faunal remains indicate  
202 controlled herding locations of the domesticated animals in the marshy, saline areas of the  
203 plain, a very different location and environment to what the earlier wild caprine and cattle of  
204 Pınarbaşı grazed (Henton, 2013; Middleton, 2018; Henton in press).

205

### 206 **2.2.2 Çamlıbel Tarlası**

207 Çamlıbel Tarlası is a small Late Chalcolithic site located 65 km south-west of Çorum in  
208 north-central Turkey which was excavated 2007–2009 as a cooperative project between the  
209 German Archaeological Institute and Edinburgh University. The site, covering 0.25 ha, has  
210 seven phases from 3590 to 3470 cal. BCE, revealing, within this short timeframe, evidence of  
211 alternating episodes of full-time occupation and sporadic, possibly seasonal visits (Schoop  
212 2008; 2009; 2011; 2015). Excavations also highlighted the importance of metallurgy: the site  
213 is located 2 km from a rich copper ore outcrop, and numerous finds of crucibles and slag  
214 attest to copper working (Marsh, 2010; Schoop, 2015). The region receives higher rainfall  
215 than the southern Konya plain, ~530 mm, but is topographically variable, and rainfall varies  
216 both annually and spatially (Erinç, 1949; Dündar, 2009; FAO, 2015). The environment  
217 surrounding Çamlıbel Tarlası experienced significant deforestation events, starting as early as  
218 the Chalcolithic (Dörfler et al., 2000; Marsh, 2010; Marston et al., 2021). There is evidence  
219 of dense canopy oak woodlands at the start of settlement at Çamlıbel Tarlası, with increasing  
220 clearance over time, due either to increased need of fuel for metallurgy and/or clearance for  
221 agriculture (Marston et al. 2021). This correlates with evidence of significant erosional events  
222 occurring at the beginning of occupation of Çamlıbel Tarlası (Marsh, 2010).

223

224 The settlement's inhabitants subsisted on a mixed agricultural suite, with remains of cattle,  
225 sheep, goat and pig, glume wheats, hulled barley, flax and numerous pulse species found  
226 (Bartosiewicz and Gillis, 2011; Papadopoulou and Bogaard, 2012; Stroud 2016; Stroud et al.,

in prep.). Isotopic investigations of the faunal and human remains at the site have revealed differences in the husbandry of cattle and caprines, as well as the possible dietary importance of cattle products and pulses to humans (Pickard et al., 2016; Pickard et al. 2017).

### **2.2.3 Kuruçay Höyük**

Kuruçay Höyük was examined floristically but not isotopically in this study, and only Late Chalcolithic remains were examined. The site, estimated to be around 1 to 1.5 ha, is located in the Lake district around 3 km from Lake Burdur and 10km from Neolithic/Chalcolithic Hacılar (Duru, 1994). Thirteen levels were identified, with the Late Chalcolithic layers 6, 6A and 3 relevant to this study (Duru, 1994). Around 23 freestanding buildings were excavated in level 6A2, the best preserved of the Late Chalcolithic phases (Duru, 2008). The destruction by fire of a number of structures resulted in the burning of crop stores, the material used within this study. Radiocarbon dates for levels 6A to 3 place the occupation levels around 3700-3100 cal. BCE (re-calibrated dates from Schoop, 2005a using IntCal 13).

Today the area is characterised as semi-arid, with ~400 mm of precipitation falling annually at the nearby town of Burdur (Erinç, 1949). Reconstruction of the past vegetation suggests a forested environment, with high amounts of arboreal pollen (van Zeist et al., 1975; Eastwood et al., 1998; Schoop, 2005b). Pollen evidence indicates a change from steppe vegetation to oak, juniper and pine forest, and it is hypothesised that this vegetation cover continued until Middle Bronze Age deforestation (van Zeist et al., 1975; Eastwood et al., 1998).

Analysis of the archaeobotanical material indicates a range of crops including barley, glume wheats, free-threshing wheat, four pulses and flax from selected storage deposits (Nesbitt, 1996; Stroud, 2016; Stroud et al., in prep.). Zooarchaeological analysis indicates the presence of cattle and sheep/goats, while pig remains show a divergence from the Konya plain and a similarity to western Anatolian animal husbandry (Deniz, 1996)

## **2.3 Isotopic background**

The stable carbon and nitrogen isotopes values of archaeological crop remains can be used to understand the water status of the plant during growth, and the isotopic composition of soil N, respectively. The ratio of  $^{12}\text{C}$  and  $^{13}\text{C}$  can provide a proxy for water availability. During photosynthesis, RUBISCO, an enzyme that converts carbon into sugars, discriminates against the heavier carbon isotope, resulting in the plant's carbon being depleted in  $^{13}\text{C}$  compared to

the atmosphere. During times of water stress, plants limit water loss by closing stomata, subsequently limiting the amount of CO<sub>2</sub> available for photosynthesis. Consequently, RUBISCO uses any available intercellular space CO<sub>2</sub>, with limited discrimination occurring. Carbon discrimination ( $\Delta^{13}\text{C}$ ) represents the discrimination seen within the plant, independent of atmospheric CO<sub>2</sub> (Farquhar et al., 1982; Farquhar and Richards 1984). Therefore, a plant that has had optimal water, and greater stomatal opening, will have more negative  $\delta^{13}\text{C}$  values and more positive  $\Delta^{13}\text{C}$  values, while plants that have been water stressed will be less depleted in  $^{13}\text{C}$  and have a lower  $\Delta^{13}\text{C}$ .

A number of studies have investigated how different crop species'  $\Delta^{13}\text{C}$  values differ under optimal and sub-optimal water availability (Araus et al., 1997; Ferrio et al., 2005; Heaton et al., 2009; Wallace et al., 2013). Research indicates that barley is 1-2‰ higher in  $\Delta^{13}\text{C}$  than wheat grown under the same conditions (Wallace et al., 2013). The difference is variety specific, with two-row barley 1‰ and six-row barley < 2‰ higher than wheat (Roche et al., 2006; Wallace et al., 2013). Styring et al. (2017b) confirmed that there is at least a 1‰ offset within archaeological data, showing that in south-west German samples six-row barley was 1.1‰ higher than (unirrigated) wheat. Lentil, the only pulse which has research into  $\Delta^{13}\text{C}$  under optimal and sub-optimal water availability has a wetter signal than wheat in water optimal conditions but a drier signal in sub-optimal conditions (Wallace et al. 2013).

The ratio of  $^{14}\text{N}$  to  $^{15}\text{N}$  in archaeological seeds is a proxy for the isotopic ratio of the soil N a plant used when growing. Stable nitrogen isotopes have been used to infer crop manuring, which due to the volatilisation of the lighter isotope as ammonia, results in an enrichment of  $^{15}\text{N}$ . A number of other factors can enrich soil  $^{15}\text{N}$ : salinity, aridity, waterlogging and microbial activity (Heaton, 1986; Handley et al., 1999; Senbayram et al., 2008; Yousfi et al., 2010; Hartman and Danin, 2010; Fraser et al., 2011). Given the study region of this research, the effect of aridity on  $\delta^{15}\text{N}$  values is particularly important. Research has shown a negative relationship between annual rainfall and  $\delta^{15}\text{N}$ , and provides a method to adjust  $\delta^{15}\text{N}$  values using relevant rainfall values, estimating the potential effect that aridity plays in elevating  $^{15}\text{N}$  (Hartman and Danin, 2010; Styring et al., 2016). It is possible to disentangle the combined effects of aridity and manuring; collagen  $\delta^{15}\text{N}$  values of wild herbivores can be used to infer a non-manured wild vegetation baseline, allowing the plant isotope values to be fixed within the wider ecosystem and provides an indication of whether the crop values differ from the surrounding vegetation (Styring et al., 2016). An enrichment above the non-manured baseline

suggests a crop field-specific enrichment and the simplest explanation of such enrichment is the application of manure.

## **2.4 Functional ecology of weed seeds background methodology**

The functional ecology of weed seeds has been used to understand the nature of crop husbandry practices (see for example Jones et al., 2000; Charles et al., 2002; Bogaard et al., 2018). As crop weed species' geographical distributions have changed over time, the direct taxonomic comparison between archaeological weed seeds and modern flora is problematic. Instead, studies have used functional traits which measure a species' potential to thrive within a given environment to distinguish between farming regimes. By comparing functional attributes of modern weed flora with those of archaeological weed species, an understanding of the intensities of different farming regimes is gained. Modern studies of weed flora found in high-input/intensity cultivation in Spain and Greece as well as low-input/intensity cultivation weeds in France and Morocco provide data to construct a model of cultivation intensity using functional attributes (Charles et al., 2002; Jones et al., 2005; Bogaard et al., 2016; 2018). A linear equation that combined four functional attributes was extracted using discriminant analysis, maximising the separation between intensive and extensive regimes. The functional attribute scores of archaeological samples are treated as unknown cases and classified using the model produced from the modern data. Archaeological samples containing weeds with functional attributes associated with low soil fertility are classified towards the "low intensity" end of the spectrum, while those with attributes associated with high fertility are classified towards the "high intensity" end of the spectrum, and would have required higher labour inputs during cultivation.

## **3. Materials and method**

### **3.1 Sample selection**

Charred crop seeds were selected for isotopic analysis from two of the three sites: Çatalhöyük and Çamlıbel Tarlası. The site of Kuruçay Höyük was not isotopically analysed. Material from Çatalhöyük came from the TP levels of Çatalhöyük East (referred to as Late Neolithic (LN) samples below) and samples from Trench 1 (dated to the ECI and ECII phases) and Trench 5 of Çatalhöyük West (dated to the ECI phase, see supplementary data for sample by sample phasing). Limited TP material was available for isotopic analysis, with 12 samples selected from hearth contexts and other primary deposits. Samples from Trench 1 and Trench

5 were selected from samples already analysed archaeobotanically, deriving from short-lived depositional deposits of a midden and containing multiple specimens of different species charred within the 'optimal charring window' of Nitsch et al. (2015). Sample selection for Çamlıbel Tarlası followed similar criteria, focusing on primary deposits from floors and hearths. Sixty-six samples from Çatalhöyük West and 121 samples from Çamlıbel Tarlası were analysed for isotopic measurements ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values). Charred remains of ten different crop species were analysed; Emmer (*Triticum dicoccum* Schübl.), einkorn (*Triticum monococcum* L.), New type glume wheat (*Triticum timopheevi* Zhuk.), free-threshing wheat (*Triticum* sp.), hulled barley (*Hordeum vulgare* L.), lentil (*Lens culinaris* Medik.), pea (*Pisum sativum* L.), bittervetch (*Vicia ervilia* (L.)Willd.), grass pea (*Lathyrus sativus* L.), and chickpea (*Cicer arietinum* L.). Three to ten seeds were used per analysis to smooth within-field variability (Nitsch et al., 2015).

### 3.2 Isotope method

Ten percent of the seeds were screened to determine carbonate, nitrate and/or humic contamination and therefore the need for pre-treatment. The samples were analysed using Fourier transform infrared spectroscopy with attenuated total reflectance: Agilent Technologies Cary 640 FTIR instrument with a GladiATR™ accessory from PIKE technologies. The samples were measured and the background noise subtracted. A baseline correction was conducted using Agilent Resolution Pro to assist in the detection of contamination by carbonates, nitrates and humics following Vaiglova et al. (2014b). The detection of a slight peak characteristic of carbonate contamination led to the acid pre-treatment of all samples.

Pre-treatment consisted of washing the crushed samples in 10ml of 0.5 M hydrochloric acid at 70 °C for 40-60 mins, after which they were washed with distilled water until a pH of neutral was reached; the samples were then freeze dried. The samples were analysed on a SerCon EA-GSL mass spectrometer at the University of Oxford Research Laboratory for Archaeology and the History of Art.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values were measured separately due to the samples' low N%. Isotopic ratios were calculated using an internal alanine standard. Two-point normalisation was conducted using IAEA-CH6 and IAEA-CH7 for  $\delta^{13}\text{C}$  and IAEA-600/Caffeine-2(U. Indiana) and IAEA-N2 for  $\delta^{15}\text{N}$ . Measurement uncertainties were monitored using an internal Alanine standard. The average measurement uncertainty, calculated using the Kragten (1994) method, for  $\delta^{13}\text{C}$  values was 0.16‰, ranging from

0.07‰ to 0.57‰ and for  $\delta^{15}\text{N}$  values was 0.30‰, ranging from 0.17‰ to 0.56‰ (see supplementary data for full analytical conditions). Any outlying samples were tested in triplicate to determine if they represented real values or machine/handling error (see supplementary data for further information on data reliability).

The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values were adjusted to account for the effect of charring by subtracting 0.11‰ and 0.31‰ from the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values, respectively (Nitsch et al., 2015). The  $\Delta^{13}\text{C}$  values of the cereal grains were calculated to allow comparison with modern data, following the Farquhar, O’Leary and Berry, (1982) equation:

$$\Delta^{13}\text{C} = \frac{\delta^{13}\text{C}_{\text{air}} - \delta^{13}\text{C}_{\text{plant}}}{1 + \delta^{13}\text{C}_{\text{plant}}/1000}$$

The approximated  $\delta^{13}\text{C}$  value of atmospheric  $\text{CO}_2$  ( $\delta^{13}\text{C}_{\text{air}}$ ) was obtained from reference tables (Ferrio et al., 2005), and calculated using the cal. BCE date range of each site.

The aridity offset was calculated followed Hartman and Danin’s (2010) regression equation and was applied to all  $\delta^{15}\text{N}$  values. The non-manured baseline was calculated using faunal collagen  $\delta^{15}\text{N}$  values from the respective sites. The baseline was calculated from the mean herbivore values, ideally wild animals, minus 4‰ for the trophic offset. A band of  $\pm 1$  standard deviation was calculated in addition to band encompassing the grain to rachis difference (2.4‰).

### 3.3 Functional weed ecology

Samples were selected for functional weed ecology analysis based on the number of weed taxa identified to species level and/or the number of taxa identified to genus level in which the genus contained less than five species. Only samples which contained ten or more seeds which fulfilled these criteria were selected, with only samples from Çamlıbel Tarlası, trench 5 at Çatalhöyük West, and Kuruçay Höyük qualifying. Specimen identification was conducted at the University of Oxford using a stereoscopic microscope. Modern reference material was accessed at the University of Oxford, the Selçuk University herbarium, Konya and the British Institute at Ankara (BIAA). The separation of arable weeds from dung fuel-derived wild/weed seeds was conducted using correspondence analysis; the weed taxa were coded based on fruiting time, seed size, and habitat preference, relevant traits identified in previous research to distinguish potentially dung-derived taxa from the arable weed species (see Stroud 2016 for more details)

Discriminant analysis was conducted using the statistical program SPSS, comparing the datasets constructed from multiple modern field research in Morocco, France, Spain and Greece (Bogaard et al., 2018). Functional attributes of the arable taxa were used to discriminate between fertility conditions under low- and high-intensity regimes. The resultant discriminant function which distinguishes between the low- and high-intensity regimes in the modern datasets was in turn used to classify the archaeological samples.

## **4. Results**

### **4.1 Çatalhöyük isotope results**

The average  $\Delta^{13}\text{C}$  values of the different wheat species all occur within 1‰ of each other, and their means plot within Wallace et al.'s (2013) optimal water availability band (Figure 2a) (See table S2 for means, standard deviations and number of samples). Einkorn ( $17 \pm 1.2\text{‰}$ ) and free-threshing wheat ( $16.9 \pm 1.2\text{‰}$ ) show high variability, with einkorn samples plotting in all water availability bands, while the other glume wheats, emmer and new type, have a narrower range and have higher means. The pulse  $\Delta^{13}\text{C}$  values indicate that they were cultivated in moderate to optimal water availability, with lentil showing a wide range of values almost as great as those of einkorn and free-threshing wheat. The similarity of hulled barley's mean  $\Delta^{13}\text{C}$  value ( $16.5 \pm 0.6\text{‰}$ ) to that of the different wheat species is noteworthy as an offset would be expected if grown under the same conditions of water availability. When different offsets are applied to the Çatalhöyük barley  $\Delta^{13}\text{C}$  values to account for the physiological differences, there are statistically significant differences. Barley is significantly lower than emmer and new type glume wheat with a 0.5‰ offset, emmer, new type, einkorn and free-threshing wheat with 1‰ offset and all cereals plus lentil with a 1.5‰ offset (Table 1). Barley has a lower average  $\Delta^{13}\text{C}$  value than the other crops when physiological differences have been accounted for, indicating that it was cultivated in drier conditions.

The Çatalhöyük samples have wide ranging  $\delta^{15}\text{N}$  values (Figure 2b) compared to published  $\delta^{15}\text{N}$  values from archaeological grains from other Mediterranean/South West Asian sites (see Vaiglova et al. 2014a; Styring et al. 2017a). Statistically there is no difference between the mean  $\delta^{15}\text{N}$  value of the five Çatalhöyük cereal species when compared together, while the pulses have a lower mean due to their atmospheric-nitrogen fixing ability and thus are not included in comparison with the cereals. The glume wheat species and barley have similar

means and ranges, with no statistically significant difference. Free-threshing wheat has a lower mean, less variability and is statistically significantly different to barley; free-threshing wheat is also significantly different from einkorn (Table S1, Table S2, Table 1). Variability is high within species, with barley samples ranging over 14‰ in  $\delta^{15}\text{N}$  values, the pulses having a slight lower range of 5‰ and einkorn and emmer spanning a 9‰ range. New type glume wheat and free-threshing wheat are relatively less variable, with ~6‰ and 4.5‰ ranges, respectively.

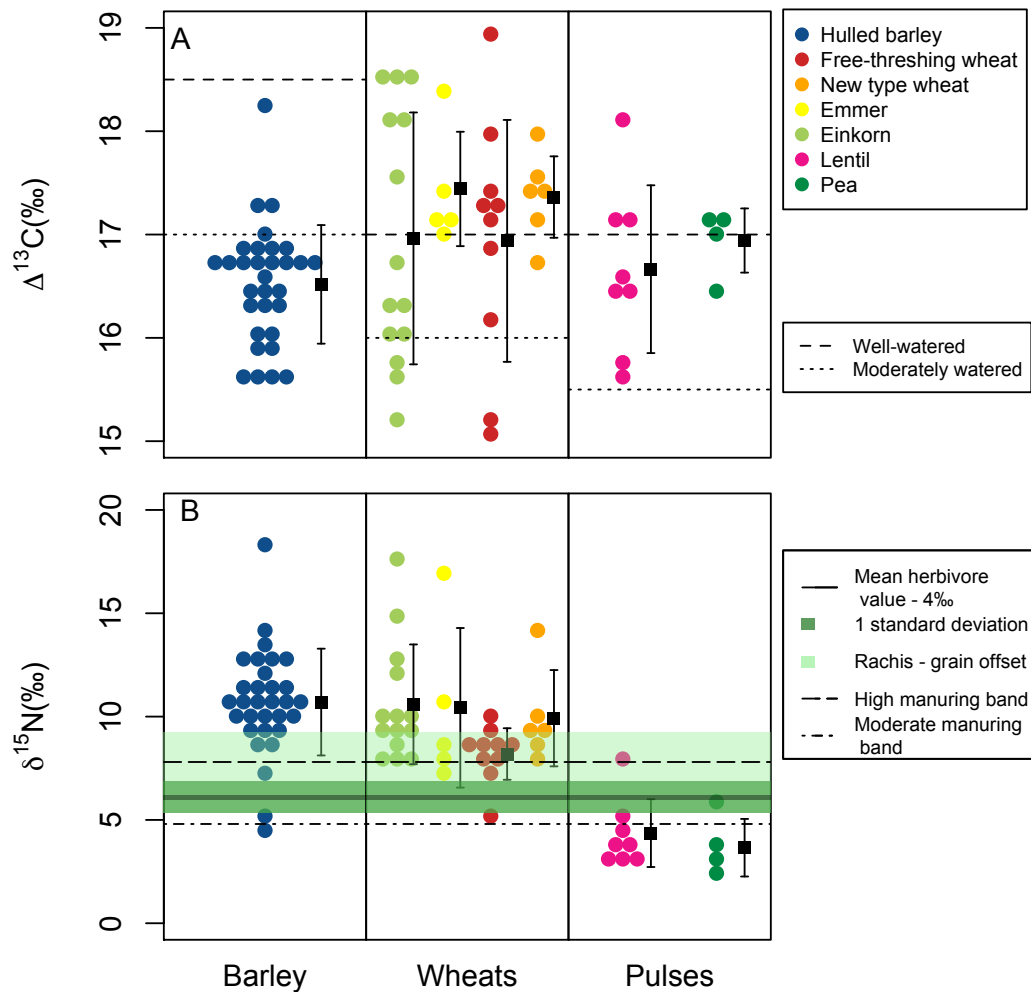


Figure 2. The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  results from all Çatalhöyük samples. **a.** shows the  $\Delta^{13}\text{C}$  results against the Wallace et al. (2013) water bands. **b.** shows the  $\delta^{15}\text{N}$  results plotted with the estimated non-manured plant base line and the associated bands which have been adjusted for aridity following Hartman and Danin (2010).

440 Table 1. The results of statistical tests on the Çatalhöyük and Çamlıbel Tarlası isotope results. Significant p-values are shown in bold.

Material		Site	Isotopic data			
Welch's ANOVA due to unequal variances				<i>F</i>	<i>df</i>	<i>p-value</i>
Cereal and pulse species,	No barley offset	Çatalhöyük	$\Delta^{13}\text{C}$	3.83	6 (18.14)	<b>0.01<sup>1</sup></b>
	0.5‰ offset			11.08	6 (18.13)	<b>&lt;0.00<sup>2</sup></b>
	1‰ offset			20.38	6 (18.14)	<b>&lt;0.001<sup>*</sup></b>
	1.5‰ offset			34.34	6 (18.14)	<b>&lt;0.001<sup>*</sup></b>
Welch's two sample T-test				<i>t</i>	<i>df</i>	<i>p</i>
Free-threshing wheat compared to barley		Çatalhöyük	$\delta^{15}\text{N}$	-4.1	32.5	<b>&lt;0.001</b>
Free-threshing wheat compared to einkorn		Çatalhöyük	$\delta^{15}\text{N}$	-2.8	18.8	<b>0.01</b>
Barley, LN compared to ECI		Çatalhöyük	$\delta^{15}\text{N}$	-2.7	3.56	0.06
			$\Delta^{13}\text{C}$	-2	3.86	0.12
Einkorn, ECI compared to ECII			$\delta^{15}\text{N}$	-1.26	4.08	0.28
			$\Delta^{13}\text{C}$	1.55	6.63	0.17
ANOVA				<i>F</i>	<i>df</i>	<i>p</i>
Cereal and pulse species	No barley offset	Çamlıbel Tarlası	$\Delta^{13}\text{C}$	4.6	5,111	<b>&lt;0.001<sup>3</sup></b>
	0.5‰ offset			2.3	5,111	0.05
	1‰ offset			3	5,111	<b>0.01<sup>4</sup></b>
	1.5‰ offset			6.7	5,111	<b>&lt;0.001<sup>5</sup></b>
Pulse species		Çamlıbel Tarlası	$\Delta^{13}\text{C}$	4.7	2,63	<b>0.01<sup>6</sup></b>
Pulse species		Çamlıbel Tarlası	$\delta^{15}\text{N}$	15.7	2,63	<b>&lt;0.001<sup>7</sup></b>

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<sup>1</sup> New type wheat is significantly different from barley (Games-Howell post hoc)

<sup>2</sup> Emmer, new type wheat and pea are significantly different from barley (Games-Howell post hoc)

\* all species significantly different from barley (Games-Howell post hoc)

<sup>3</sup> Einkorn and Grass pea are significantly different from barley (Tukey post hoc)

<sup>4</sup> Bitter vetch is significantly different from barley (Tukey post hoc)

<sup>5</sup> Bitter vetch and lentil are significantly different from barley (Tukey post hoc)

<sup>6</sup> Grass pea is significantly different from bitter vetch (Tukey post hoc)

<sup>7</sup> Grass pea and lentil are significantly different from bitter vetch (Tukey post hoc)

The high enrichment in  $^{15}\text{N}$  of some samples exceeds values for most recorded archaeological samples, as well as many intensive modern manuring projects based on cattle and sheep dung inputs (Bogaard et al., 2007; Fraser et al., 2011; Styring et al., 2017a). High values have been noted in modern manured oasis fields in Morocco averaging at 15‰ and similar to Çatalhöyük values (Styring et al., 2016). Comparison with the aridity-adjusted  $\delta^{15}\text{N}$  manuring band of Bogaard et al. (2013) shows that all cereals plot within the high manuring band. As multiple factors can cause the  $^{15}\text{N}$  enrichment of an ecosystem, an extrapolated non-manured plant baseline was constructed from Çatalhöyük West wild and domesticated animals. Both wild and domesticated animals were used because research indicates some grazing of non-arable areas by domestic animals (Middleton, 2018). The high value of the non-manured plant baseline indicates that there is some degree of ecosystemic enrichment. This may limit the relevance of the manuring bands to infer the degree of manuring at the site. Comparison with the un-manured baseline shows elevation of plant samples above the baseline except for the pulses. As pulses are atmospheric nitrogen fixers it is expected that they would be close to 0 but the average value of all pulses is 4.1‰. This elevation does suggest some degree of manuring at the site, coupled with environmental enrichment.

When Çatalhöyük  $\Delta^{13}\text{C}$  values are divided by phase, statistically there is no significant difference between the periods of taxa with three or more samples analysed (barley and einkorn) (Figure 3, Table 1). There appears to be a constant trend for barley to have  $\Delta^{13}\text{C}$  values indicative of less than optimal water availability; however limited samples in ECII make statistical comparison problematic.

$^{15}\text{N}$  enrichment is constant through time for most species (Figure 3). Barley shows overall higher  $^{15}\text{N}$  values, which may be an effect of aridity seen within the  $\Delta^{13}\text{C}$  values. Comparisons between the phases in terms of  $\delta^{15}\text{N}$  values for each species are limited by the low number of samples in particular phases. Barley, however, can be compared between the Late Neolithic and Early Chalcolithic I period and einkorn from the ECI and ECII, and there are no significant differences (Table 1).

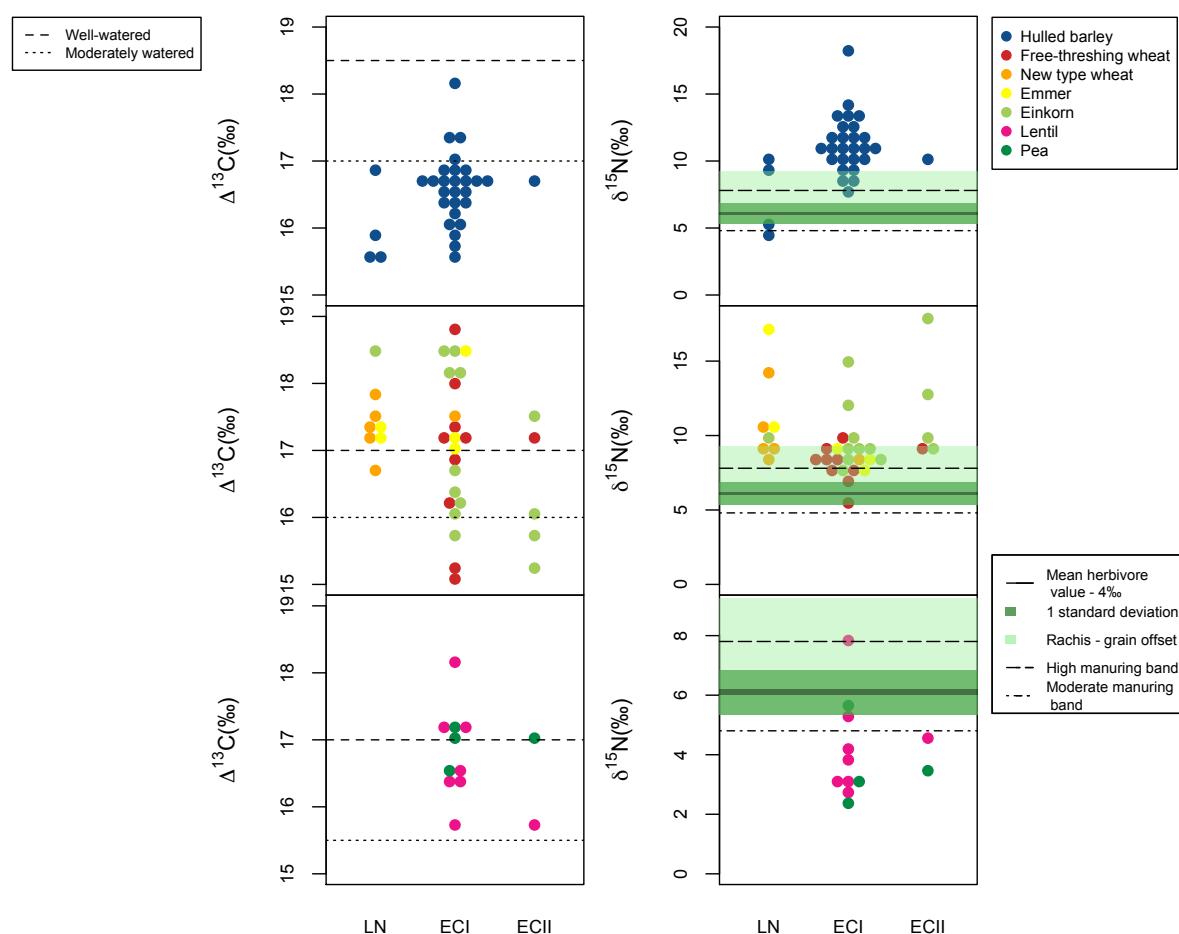


Figure 3. The Çatalhöyük isotope samples separated by the three phases represented and graphed against the Wallace et al. (2013) water availability bands (carbon) and the Bogaard et al. (2013) manuring bands and un-manured baseline (nitrogen) which have been adjusted to account for aridity based on Hartman and Danin (2010).

## 4.2 Çamlıbel Tarlası isotope results

The mean  $\Delta^{13}\text{C}$  values of barley, wheats and pulses indicate moderate to optimal water availability (Figure 4a). The archaeobotanical remains suggest that the barley variety at the site is either two-row or a combination of two- and six-row barley. Statistically barley is significantly different without an offset from einkorn and grass pea, while the addition of a 0.5‰ offset results in no statistical difference and a 1.5‰ offset shows a statistically significant difference between the barley and the two main pulse species, lentil and bitter vetch (Table 1). This possibly indicates the cultivation of barley in slightly drier conditions than the pulses, but the limited modern research into the water availability offsets for pulses other than lentil limits the conclusions. The  $\Delta^{13}\text{C}$  values from the Çamlıbel Tarlası samples are highly variable within species, with values occurring in all water availability bands for

hulled barley, emmer, lentil and bitter vetch indicating a wide range of water availability in the crop fields.

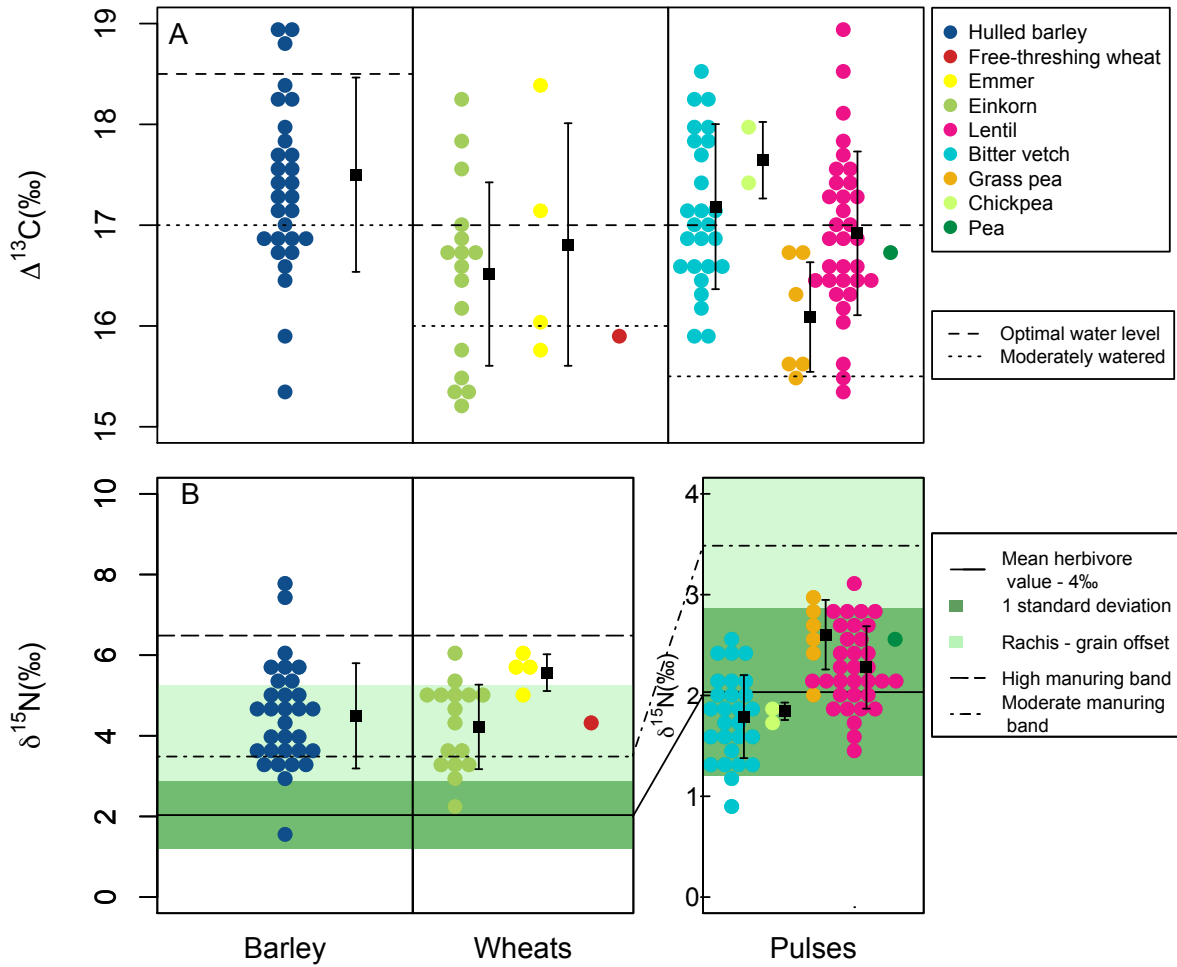


Figure 4. The Çamlıbel Tarlası isotope values. **a.** shows the  $\Delta^{13}\text{C}$  values plotted against the Wallace et al. (2013) water availability bands. **b.** shows the  $\delta^{15}\text{N}$  results plotted against the Bogaard et al. (2013) manuring bands adjusted for the effects of aridity, and the un-manured plant baseline.

$\Delta^{13}\text{C}$  values differ between the three main pulse species, with the two dominant pulse crops – lentil and bitter vetch – having similar means that fall within the optimal/moderate water bands. Grass pea's mean is lower and statistically different from bitter vetch (Table 1).

Comparative modern experiments have as yet only been conducted on lentil, so it is uncertain whether such differences are environmental or physiological.

Regarding  $\delta^{15}\text{N}$  values, the Çamlıbel Tarlası cereal species are similar to each other, while there is the expected difference between cereals and pulses due to the pulses' atmospheric N-fixing ability (Figure 4b). Bitter vetch has a lower mean ( $1.8 \pm 0.1\text{‰}$ ) than lentil ( $2.2 \pm 0.1\text{‰}$ ) and grass pea ( $2.6 \pm 0.1\text{‰}$ ), and is statistically significant different to both (Table 1).

The crop  $\delta^{15}\text{N}$  values are enriched above the un-manured baseline, while the majority of cereal samples plot in the (aridity-adjusted) moderate manuring band (Figure 4b). Given Çamlıbel Tarlası's higher rainfall, aridity has a limited effect, with the band adjusted by only 0.48‰. The enrichment of the cereals above the forage band is ~3‰ indicating some degree of arable field enrichment most likely originating from low to moderate manuring levels.

Comparison by phase is limited by low sample numbers. Examination of taxa occurring in two or more phases shows that high  $\Delta^{13}\text{C}$  variability occurs in all phases, and eliminates temporal change as the source of variability (Figure 5). The four phases show similar results to the overall site  $\Delta^{13}\text{C}$  values, with all species' values plotting towards the optimal water availability range. There is continuity in species  $\delta^{15}\text{N}$  values between phases, as well as no significant difference between the species within phase (Figure 5).

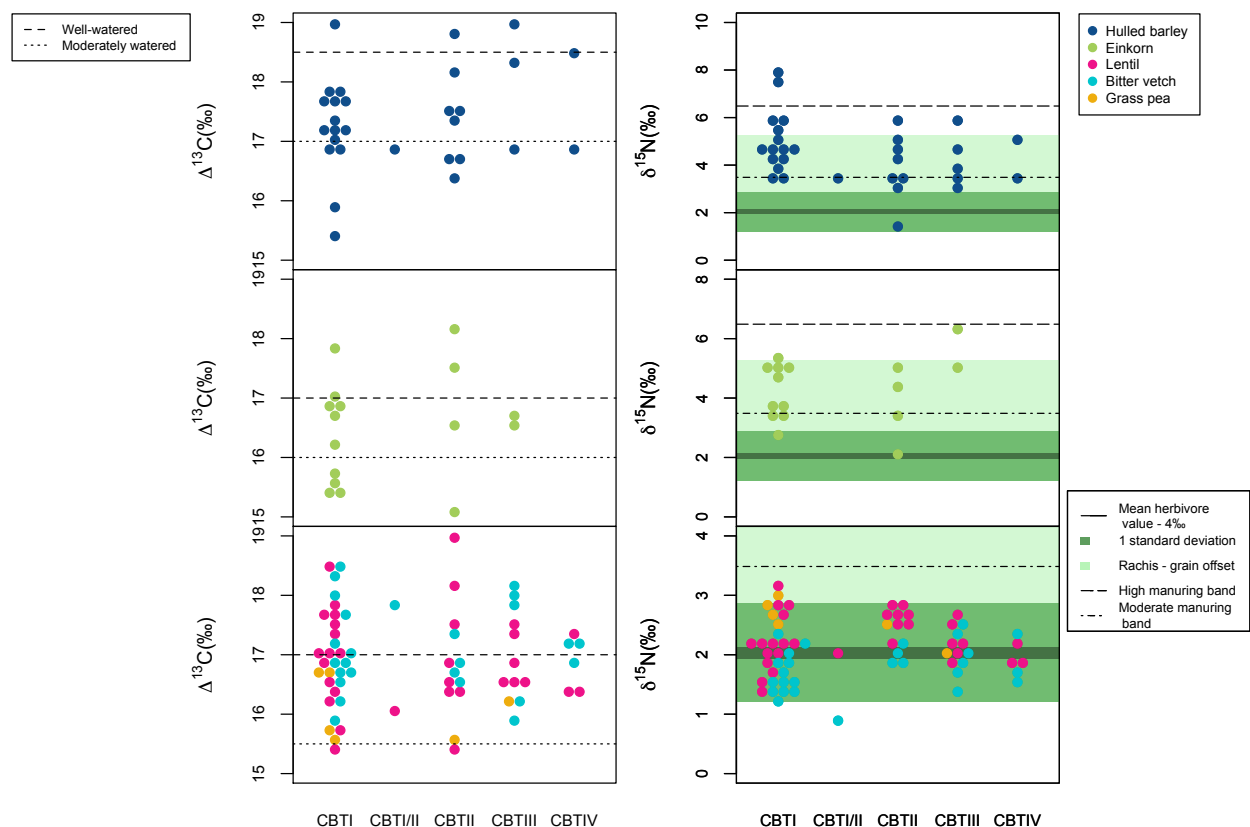


Figure 5. The  $\Delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values from Çamlıbel Tarlası plotted by phase, showing the Wallace et al. (2013) water availability thresholds (carbon) and the Bogaard et al. (2013) manuring bands (adjusted for aridity based on Hartman and Danin (2010)), as well as the un-manured baseline (nitrogen). Only crops species which occur in three or more phases are shown.

### 4.3 Functional weed ecology

Investigation into the intensity of arable cultivation (labour input per unit area relating particularly to soil fertility) indicates that the Çatalhöyük West Trench 5 samples represent a range of crop husbandry “intensities” (Figure 6C). The samples’ contexts may have had an impact as the samples come from midden deposits and thus there may be some mixing. This is a disadvantage due to the lack of storage samples from the site, which would have provided information about the growing conditions of specific crop species. Regardless, while the samples are highly variable they tend to fall towards the intermediate to low-intensity side of the spectrum with a minority of high-intensity samples. Investigation into the intensity of arable cultivation of the Çamlıbel Tarlası archaeological samples reveals a concentration in the centre of the intensity continuum. (Figure 6E). Examination of the different phases of the site indicates limited chronological variation in crop husbandry intensities. The crop husbandry intensities represented in the weeds of storage samples from the Late Chalcolithic site of Kuruçay Höyük show noticeable similarity with the Çamlıbel Tarlası samples, falling in the middle of the intensity continuum (Figure 6D). While there are limited Kuruçay Höyük samples there are indications that glume wheats were possibly less intensively cultivated than the other species.

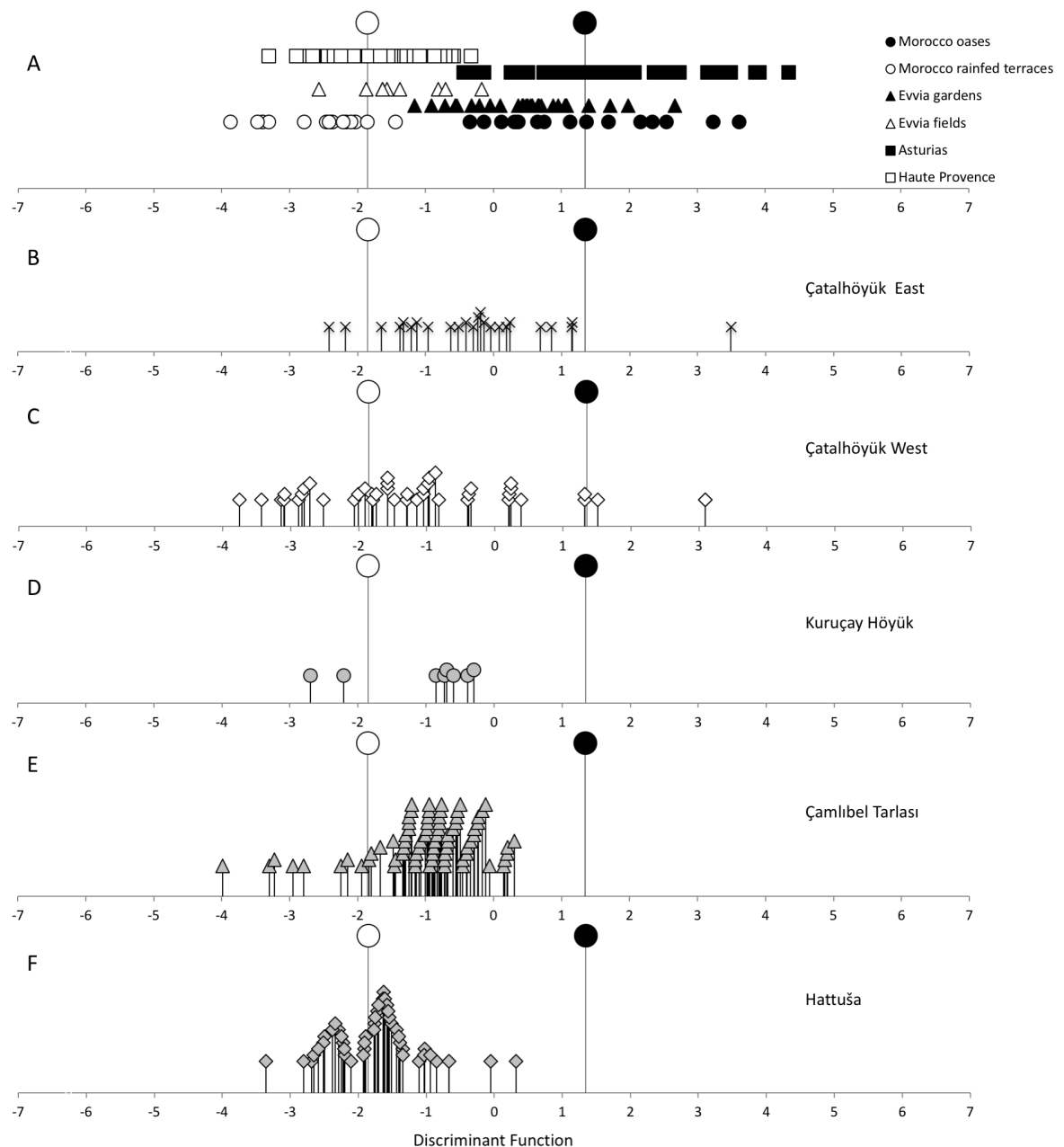


Figure 6. The results of functional weed ecology analysis with **A.** showing the discriminant scores from the weeds association from modern field studies of low and high intensity regimes, **B.** shows the results from the classification of the *Çatalhöyük East* samples from Green et al. (2018), **C.** shows the results from the classification of the *Çatalhöyük West Trench 5* samples, **D.** shows the results of the *Kuruçay Höyük* samples' classification, **E.** shows the results of the classification of the *Çamlıbel Tarlası* samples and **F.** shows the results of the classification of the *Hattuša* samples from Diffey et al. (2020).

Similar functional ecological analysis of the weed composition of earlier and later assemblages – from Neolithic *Çatalhöyük East* (Green et al. 2018), and from Late Bronze Age site *Hattuša* (Diffey et al. 2020) – provides an opportunity to investigate changes in agricultural intensities over a longer temporal span in central Anatolia. Such comparison shows a gradual shift towards lower inputs per unit area – and hence more extensive cultivation regimes – over time (Figure 6). Comparison of the *Çatalhöyük East* and *Çatalhöyük West* samples shows similarly variable intensities, but with a slight shift towards

lower discriminant scores at Çatalhöyük West. Comparison of the Late Chalcolithic Çamlıbel Tarlası and Kuruçay Höyük discriminant scores with those for a subterranean crop storage complex at Hattuša (early 16<sup>th</sup> century BCE) (Diffey et al. 2020) again suggests that the later assemblage is associated with lower intensity. The clearest difference is apparent between the relatively high-intensity scores for Çatalhöyük East and the low-intensity range for Hattuša.

## 5. Discussion

The stable isotope and functional weed ecological analyses show the variety of crop growing conditions at the three sites. The sites share some taxa: barley, emmer, einkorn and lentil are sufficiently represented at both sites to allow comparison of isotope values. At Çatalhöyük, regardless of phase, barley has a dry signal, lentil moderate and emmer and einkorn wet. At Çamlıbel Tarlası all these crops were grown under moderate water conditions. Nitrogen results show a possible anthropogenically enriched signal on top of the ecoystemic enrichment at Çatalhöyük West and a low to moderate manuring signal at Çamlıbel Tarlası. The functional weed ecology results indicate a wider range of intensities at Çatalhöyük West, while there is a narrower range of intermediate intensities at Çamlıbel Tarlası and Kuruçay Höyük.

The samples from Çatalhöyük indicate a wide range of conditions under which crops were cultivated. The dryland anabranching channel system which surrounded the site provided a mosaic of wet and dry locations for cultivation (Ayala et al., 2017) and the isotopic results indicate that the inhabitants of the site selected specific locations within the landscape for cultivation based on the requirements of the crop species. Barley was cultivated in a specific niche which allowed the inhabitants of Çatalhöyük to exploit the drought-tolerant nature of the species, allowing dry areas around the site to be utilised for crop production. This meant that the more water-demanding wheats and pulses could be cultivated in soils with higher water availability, such as closer to water channels around the site. The high variability in crop husbandry intensity represented by the weeds confirms that the people of Çatalhöyük cultivated their crops using a variety of techniques and in a wide range of field locations possessing wide ranging soil fertility and <sup>15</sup>N values. The wide range of both  $\Delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values indicates cultivation locations ranging from wet soils nearer the streams to the drier hummocks, together with the possible enrichment of areas surrounding the occupation mound, and abandoned parts of Çatalhöyük East. Such a variety of locations would encompass a wide range of soil types and proximity to manure sources, which would

consequently result in a range of  $\delta^{15}\text{N}$  values and weed ecology values. The wide range of  $\delta^{15}\text{N}$  values suggests that a combination of environmental processes resulted in enrichment of  $^{15}\text{N}$ . The high cycling of water within the landscape (a wet location within an arid region), coupled with possible seasonal wetting and drying and/or waterlogging, would be expected to produce a wide range of  $\delta^{15}\text{N}$  values across the landscape. Consequently, different microbial activity would result in variable soil  $^{15}\text{N}$  enrichment; seasonal wetting and drying and/or waterlogging for example provide anaerobic environments for denitrifying bacteria. The wide range of  $\delta^{15}\text{N}$  values, some of which are enriched above the inferred non-manured plant values, also suggests that manure may have been used on different scales around the site in addition to the already variable soil  $^{15}\text{N}$  values. The results suggest manuring may have ranged from limited addition of manure to more intensive use, and this is supported by the range of “intensities” seen in the weed ecology. Domestic sheep, goat and (by the West Mound occupation) cattle were present at the site and could have provided manure for the fields. Archaeobotanical evidence demonstrates the use of dung as a fuel source on the settlement (both Çatalhöyük East and West) and therefore the collection of dung for manure is also highly possible (Bogaard et al 2013; Stroud 2016).

The variable nature of the crop husbandry evident in the Çatalhöyük West samples could be the result of inter-house differences, a continuation of trends observed from Çatalhöyük East samples (Green et al., 2018), potentially due to differential access to resources such as labour, manure or nearby land. Distance from site to field could play a role in shaping crop husbandry: ethnographic research has indicated that the further fields are from a settlement the less labour/resource is used to cultivate them (Jones et al., 1999; Jones, 2005). While the population of Çatalhöyük West was lower than the Çatalhöyük East peak of around 6500 cal. BCE, changes in the surrounding landscape during the Early Chalcolithic, including the development of a large marshy area south of Çatalhöyük West (Ayala et al., 2017), likely restricted the use of that nearby land for crop husbandry, requiring some people to cultivate further afield. The postulated idea of land tenure used at classic Çatalhöyük East, based on a supra-household level with radial wedges perhaps used by particular neighbourhoods (Bogaard et al., 2017), cannot be directly translated to Çatalhöyük West. The limited area of the site excavated so far restricts detailed understanding of neighbourhoods, though remote sensing does hint at a different building organisation on Çatalhöyük West, possibly in a NE-SW alignment (Forte et al., 2019). What is clear is that different areas within the landscape surrounding Çatalhöyük West were utilized for the cultivation of crops. These different

physical aspects of the surrounding landscape and the variable nature of inputs in the crop fields would have produced a mosaic landscape of fields which had different soil water content, fertility, soil N and different access to labour and manure.

The Çamlıbel Tarlası results indicate highly variable water availability within species and a limited range of crop husbandry intensities reflected in the functional weed attributes. The wide range of the  $\Delta^{13}\text{C}$  values may reflect the cultivation of the crops in the topographically varied area surrounding the site. The wide  $\Delta^{13}\text{C}$  range could represent the difference in slope within the fields, ranging from the more arid crowns of the hills to the wetter valley bottoms (cf. Bogaard et al., 2016). The nitrogen isotope results show low level enrichment, possibly through manuring, as some of the values are enriched above the inferred un-manured plant values. Manuring is also consistent with crop husbandry intensity seen in the functional ecology of the weed flora which indicates a moderate fertility. Zooarchaeological evidence of a high proportion of cattle at the site, along with goat, sheep and pig (Bartosiewicz and Gillis, 2011), indicates a dung source. The Çamlıbel Tarlası results suggest a consistent, cohesive set of crop husbandry techniques at the site, despite the hypothesized gaps in occupation. The consistent cohesive set of crop husbandry techniques likely relates at least in part to the limited size of the site, at only 0.25ha. Such small size could reduce crop husbandry variability due to its restricted arable catchment, with potentially just one or a couple of families cultivating on the site.

The similarity of crop husbandry intensities at the two Late Chalcolithic sites of Çamlıbel Tarlası and Kuruçay Höyük suggests a similar set of crop husbandry methods. The larger size of Kuruçay Höyük (~1ha) compared to Çamlıbel Tarlası (0.25ha) suggests the occupation of Kuruçay Höyük by multiple families and the cohesive crop husbandry methods indicate a similarity between households, something which is not seen at the much larger Early Chalcolithic site of Çatalhöyük West with its variable crop husbandry intensities. Both Çamlıbel Tarlası and Kuruçay Höyük are in wetter climatic zones in comparison to Çatalhöyük West; however the smaller size of the Late Chalcolithic sites likely also played a role in shaping the crop husbandry methods used, focusing the communities on cultivating in one specific way. Together with a milder climate which limits water stress, there was no need to cultivate selectively drought tolerant species in dry areas, helping to shape a cohesive crop husbandry suite used by all inhabitants of the site. It is difficult to extrapolate further on the similarity in crop husbandry methods for the Late Chalcolithic sites, due to the lack of

isotopic data from Kuruçay Höyük. There are similarities in crop suite and weed flora at the two sites (Stroud 2016; Stroud et al., in prep), and coupled with the similar crop husbandry intensities scores this could potentially indicate a Late Chalcolithic form of crop husbandry. However, this is based only on two sites which are spatially separated by 450 Km. Any further inferences require more Late Chalcolithic sites within the region, something which is currently lacking.

Comparison of the functional weed ecology of the Chalcolithic sites with Neolithic Çatalhöyük East and Late Bronze Age Hattuša provides an opportunity to consider longer term trends. The discriminant scores for the newly presented sites here, in addition to the published sites, indicate a general trend over time in central Anatolia towards forms of agriculture involving lower inputs per unit area but potentially a larger scale of farming per household or farming unit. While the differences in environment and settlement size between the sites on the Konya plain and Kızılırmak river region cannot be disregarded, a possible ingredient in the trend towards extensive cultivation could have been the increased use of animal traction (Halstead 2014; Bogaard et al. 2019). However, a myriad of other social, cultural and environmental factors could have played a role in the perceived shift towards extensive cultivation. Further research on both large and small Late Chalcolithic and Early Bronze Age sites is needed to provide a clearer indication of any development through time of a trend towards extensive cultivation.

## **6. Conclusion**

Stable carbon and nitrogen isotopes analysis of crop remains from Çatalhöyük and Çamlıbel Tarlası, as well as functional ecological analysis of weed assemblages at Çatalhöyük West, Çamlıbel Tarlası and Kuruçay Höyük, have revealed site-specific cultivation methods during the Chalcolithic. Site size and environment were likely key contributing factors shaping crop cultivation methods. Demographic pressure at the larger sites, with large populations exploiting the surrounding landscape, especially in regions of less agriculturally favourable environments, would increase pressure on resources – including food, land, labour and manure. The large Early Chalcolithic site of Çatalhöyük West, situated in a more arid environment, and with a larger population to feed, cultivated drought-tolerant barley on drier soils, allowing wetter regions of the landscape to be used for the cultivation of wheats and pulses. Manuring is difficult to rule out; ecosystemic elevation in  $\delta^{15}\text{N}$  values is seen also in the fauna but there are some crop samples elevated above the un-manured baseline. Finally,

the mosaic nature of the landscape meant that crop husbandry intensities varied depending on field location within the landscape.

By contrast individual species were cultivated in a range of growing conditions at the small Late Chalcolithic site of Çamlıbel Tarlası. The wetter climate and small human population meant that no species was specifically selected for cultivation on drier soils. Differences in water availability within individual fields may have been exaggerated by the high degree of slope variation in this hilly setting. Manuring of fields was moderate and the weed ecology indicates a cohesive set of intermediate crop husbandry intensities, a pattern replicated from the other Late Chalcolithic site of Kuruçay Höyük.

## Acknowledgments

The research reported here was funded by the European Research Council (AGRICURB project, grant 312785, PI Bogaard), the St Cross Archaeology Graduate Scholarship (Stroud), and the British Institute at Ankara Strategic Research Initiative Study Grant (Stroud). Many thanks go to Dr Ulf-Dietrich Schoop, Director of the Çamlıbel Tarlası excavations, Prof. Peter Biehl, Dr Eva Rosenstock and the Çatalhöyük West team, Dr Mark Nesbitt, and Prof. Arkadiusz Marciniak. Thanks again go to Ulf, Eva, Peter and Arek as well as two anonymous reviewers for comments on a draft version of this manuscript.

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## Supplementary data 1

### **Data Reliability**

The reliability of the isotopic data was determined using multiple methods and protocols. Specific protocols such as visual inspection of charring morphology ensured that the most suitable samples were selected for analysis with Fourier-transform infrared spectroscopy (FTIR) used to screen for contaminants. The isotopic data were examined for outliers, which were checked in triplicate, while %C, %N, C:N and mass were used to compare against modern datasets. Each method has advantages and disadvantages and there are no set data reliability criteria for charred plant remains, unlike collagen which, due to its chemical structure, has set C:N ratios which allow reliability to be gauged (DeNiro 1985). Species-

specific differences, as well as the effect of charring and modern crop breeding all combine to make it challenging to determine data reliability, but by using multiple methods as well as the comparison of plant isotopic values to animal isotopic data, reliability can be assessed.

### ***Seed selection***

Seeds were selected based on a number of criteria in an attempt to remove any issues arising from the measurement of unsuitable grains. The desired context of the seeds was primary deposits where possible and, in the case of Çatalhöyük West, secondary contexts that contained articulated bone or fine lenses of material suggesting rapid, small-scale deposition. The grains were also assessed on the basis of morphological criteria to ascertain charring conditions. Only seeds which visually fell within the 215-260°C charring window were selected. The morphological criteria were based on Charles *et al.* (2015), while species not included in that study were assessed based on the charring collection from Nitsch *et al.* (2015). Determining the charring conditions is an important step as the plant isotopes are compared to animal collagen isotope data, as well as uncharred modern seed isotopic values. Consequently, the application of a charring offset was required – with the current offset based on seeds charred between 215°C and 260°C (Nitsch *et al.* 2015).

### ***Contamination and pre-treatment***

As explained in the main text, FTIR was conducted to detect potential exogenous carbonates, nitrates and humics. Çatalhöyük material in this study had carbonate contamination, with FTIR detecting a carbonate peak at 870 cm<sup>-1</sup> (as per Vaiglova *et al.* 2014b). To remove the carbonate contamination all samples were pre-treated as detailed in the main text. Detection of carbonate peaks in the FTIR spectra from Çamlıbel Tarlası material also indicated that of all Çamlıbel Tarlası samples required pre-treatment for carbonate contamination (see paper for pre-treatment detail).

### ***Outlier retesting and C:N ratio examination***

Any samples with outlying values were tested in triplicate to determine if they represented real values or machine/handling error. If similar results were returned, the three measurements were averaged, and that value was used. If the re-runs returned different results the outlying result was excluded as an error.

Previous studies have looked at reliability by comparing archaeological samples with modern experimentally charred (Vaiglova *et al.* 2014b; Bogaard *et al.* 2013). The C:N ratios of the archaeological samples in this study, when compared to modern experimentally charred material, show differences. However, it is important to remember that carbon samples are run independently of the nitrogen samples, which introduces a large amount of error to the C:N ratio due to differences between the different runs. The high percentage of nitrogen in the Çatalhöyük samples means that there is a statistically significant difference between the C:N ratios of archaeological cereals and modern samples (Student t-test of equal variance  $t(830) = 5.78$ ,  $p < 0.001$ ) but not between the C:N ratios of pulse samples and the modern pulse seeds (cf. Vaiglova *et al.* 2014b). The different C:N ratios of archaeological cereals and modern samples is however not due to nitrate contamination of the archaeological samples. FTIR screening indicated carbonate but no nitrate contamination, and the carbonate contamination pre-treatment process should have removed any water-soluble nitrates. Therefore, alternative explanations need to be investigated for these high %N values. Recent developments in crop science have led to a decrease in the %N of cereal grains as larger carbohydrate-rich grains have been selected for (Triboi *et al.*, 2006). It is possible that the higher %N of the Çatalhöyük cereals is in part due to the specific landraces under cultivation compared to a modern cultivate bred for low %N. Furthermore, examination of available %N values from isotopic analysis of archaeobotanical samples from SW Asia shows that there is a trend for high %N in archaeological material derived from arid environments, such as material from Çatalhöyük East, Tell Brak, and Hamoukar (Styring *et al.*, 2017a; Vaiglova, et al 2014b). Çamlıbel Tarlası samples have C:N ratios which are more similar to the modern grains. Compared with the modern charred grains, the Çamlıbel Tarlası grains fall within the same C:N range and there is no statistically significant difference. It is possible that differences seen in C:N ratio between the two sites is due to a combination of local environmental conditions and landrace grown.

#### **$\delta^{15}\text{N}$ values, %N and mass**

The higher %N in the Çatalhöyük samples does coincide with overall higher  $\delta^{15}\text{N}$  values. Because of this, the data were checked for reliability in additional ways.

Firstly, an examination of the Çatalhöyük  $\delta^{15}\text{N}$  values by species was conducted to confirm that the expected differences between pulse and cereal  $\delta^{15}\text{N}$  values existed; pulses are

expected to be lower in  $\delta^{15}\text{N}$  due to their ability via rhizobia to fix atmospheric N. There is a difference between the Çatalhöyük cereal and pulse values, conforming to the expected difference due to their different nitrogen source (Welch Two sample t-test, p-value < 0.001).

Secondly, a comparison was conducted between the Çatalhöyük data from this study and published Çatalhöyük East data (Vaiglova *et al.* 2014b; Vaiglova 2016). This was to confirm similarity in values and to check that the higher N% and  $\delta^{15}\text{N}$  were not due to the particular contexts of selected grains in this study. The published Çatalhöyük East samples have similar values to those presented in this study. Neither cereals nor the pulses from the two groups are statistically significantly different (Welch two sample t-test, cereals: p-value = 0.17, pulses: p-value = 0.65).

Finally, collagen isotope data from Çatalhöyük West fauna were considered to understand if animals were also enriched in  $^{15}\text{N}$ . If this was the case then the enrichment in  $^{15}\text{N}$  in the plants may represent an ecosystem-wide enrichment. The faunal results do indicate a  $^{15}\text{N}$  enrichment (Middleton 2018), as they do on the East Mound (Larsen *et al.*, 2019). Middleton (2018) found that there is a trend for increasing enrichment in  $^{15}\text{N}$  over time on the Konya plain, with the Çatalhöyük West faunal samples the most elevated compared to older Çatalhöyük material. It is suggested that one of the causes of the high faunal  $\delta^{15}\text{N}$  values could be the high  $\delta^{15}\text{N}$  values of plants, a consequence of enrichment in  $^{15}\text{N}$  in the soil (Pearson *et al.*, 2007; Pearson 2013; Middleton 2018). This enrichment suggests an ecosystem wide elevation in  $^{15}\text{N}$  – most likely due to the environment surrounding site. The arid climate, the seasonal wetting and drying and in some cases waterlogging all could have combined to elevate the natural soil  $^{15}\text{N}$  (Fraser *et al.*, 2011; Handley *et al.*, 1999; Hartman and Danin, 2010; Heaton, 1986; Yousfi *et al.*, 2010)

Çamlıbel Tarlası does not display the significant elevation in  $^{15}\text{N}$  seen at Çatalhöyük. However, the same steps were taken to confirm the reliability of the data. The pulses from Çamlıbel Tarlası have values lower than cereal, something expected of plants that possess the ability to fix atmospheric N (Welch two sample t-test p-value < 0.001). The claim by some authors (see Hartman *et al.* 2020) that all pulses, as atmospheric nitrogen fixers, should be within 1‰ of zero is misleading. Modern studies have shown that in some cases pulses will use soil N instead of atmospheric N – high levels of manure being one of them (Fraser *et al.* 2011; Szpak *et al.*, 2014; Treasure *et al.*, 2016). Furthermore, studies have shown that  $\delta^{15}\text{N}$  of

vegetative matter of a legume species is dependent on species and rhizobial strain (Steele *et al.* 1983). Most *modern* pulses may be within 1‰ of zero as modern seeds are commonly inoculated with specific rhizobia and grown with chemical fertilisers. However, understanding of the availability of the required rhizobia or its strain, in the past is unknowable, nor is it known how past agriculture techniques and specific environmental conditions would have affected such rhizobia and the plants overall  $\delta^{15}\text{N}$  value. Further research needs to be conducted on multiple species of legumes and different rhizobia strains to determine their effects on  $\delta^{15}\text{N}$ .

Recent research by Hartman *et al.* (2020) has drawn a correlation between  $\delta^{15}\text{N}$  of lentils and the mass and density of a seed, with the authors suggesting that lower mass seeds are more likely to have erroneous  $\delta^{15}\text{N}$  values. As Hartman *et al.*'s study was published after the research reported here was conducted it is not possible to directly compare their results with ours as we did not record the dimensions of the individual seeds, which would allow the calculation of density. Comparison of seed mass and  $\delta^{15}\text{N}$  is possible to some extent; however, unlike Hartman *et al.* (2020), this study examined bulk batches of seeds – therefore the  $\delta^{15}\text{N}$  is not directly relatable to a single seed's mass. Instead the average seed weight was calculated by dividing the total weight of a sample by the number of seeds within that sample. Comparing the Çatalhöyük lentil samples by average weight per seed to  $\delta^{15}\text{N}$  shows no evidence for a trend for lighter seeds to be higher in  $\delta^{15}\text{N}$ . A regression model of the data produces a very low  $R^2$  value of 0.0075 and an insignificant P-value of 0.8. How mass and  $\delta^{15}\text{N}$  relates for other species is debatable and comparison between all pulse samples from Çatalhöyük is difficult due to the inherently higher mass of the peas compared to lentils. Peas present the opposite trend to that expected from Hartman *et al.* (2020), with the highest  $\delta^{15}\text{N}$  value from the sample which has the largest mass. Çamlıbel Tarlası has a larger range of pulse samples than Çatalhöyük. A linear regression of the lentil samples from Çamlıbel Tarlası shows no significant relationship, with the model producing a  $R^2$  of 0.0004, and a p-value of 0.94. Comparison with the other pulses is difficult, due to the difference in mass between the lighter lentils and the heavier grass pea.

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1195

1196

Labcode/ID	Trench/area	Phase	Unit/Flot	
			number	Species
TP012	TP area, Catalhoyuk East	LN	15278	Einkorn
TP010	TP area, Catalhoyuk East	LN	13508	Emmer
TP011	TP area, Catalhoyuk East	LN	15278	Emmer
TP005	TP area, Catalhoyuk East	LN	15829s8	Hulled barley
TP006	TP area, Catalhoyuk East	LN	15829s6	Hulled barley
TP007	TP area, Catalhoyuk East	LN	15829s2	Hulled barley
TP008	TP area, Catalhoyuk East	LN	15829	Hulled barley
TP001	TP area, Catalhoyuk East	LN	15827	New type wheat
TP002	TP area, Catalhoyuk East	LN	13521	New type wheat
TP003	TP area, Catalhoyuk East	LN	15269	New type wheat
TP004	TP area, Catalhoyuk East	LN	15278	New type wheat
TP009	TP area, Catalhoyuk East	LN	13508	New type wheat
CW1T005	Trench 1, Catalhoyuk West	ECI	4382	Einkorn
CW1T009	Trench 1, Catalhoyuk West	ECI	5767	Einkorn
CW1T010	Trench 1, Catalhoyuk West	ECI	5767	Einkorn
CW1T001	Trench 1, Catalhoyuk West	ECI	4243	Emmer
CW1T020	Trench 1, Catalhoyuk West	ECI	5740	Emmer
CW1T002	Trench 1, Catalhoyuk West	ECI	4232	Free-threshing wheat
CW1T011	Trench 1, Catalhoyuk West	ECI	5540	Free-threshing wheat
CW1T022	Trench 1, Catalhoyuk West	ECI	4444	Free-threshing wheat
CW1T026	Trench 1, Catalhoyuk West	ECI	5596	Free-threshing wheat
CW1T003	Trench 1, Catalhoyuk West	ECI	5655	Hulled barley
CW1T006	Trench 1, Catalhoyuk West	ECI	5779	Hulled barley
CW1T008	Trench 1, Catalhoyuk West	ECI	5778	Hulled barley
CW1T012	Trench 1, Catalhoyuk West	ECI	5701	Hulled barley
CW1T014	Trench 1, Catalhoyuk West	ECI	4109	Hulled barley
CW1T025	Trench 1, Catalhoyuk West	ECI	5596	Hulled barley
CW1T004	Trench 1, Catalhoyuk West	ECI	4243	Lentil
CW1T007	Trench 1, Catalhoyuk West	ECI	5598	Lentil
CW1T018	Trench 1, Catalhoyuk West	ECI	4232	Pea
CW1T016	Trench 1, Catalhoyuk West	ECII	1490	Einkorn
CW1T019	Trench 1, Catalhoyuk West	ECII	1490	Einkorn
CW1T021	Trench 1, Catalhoyuk West	ECII	1514	Einkorn
CW1T024	Trench 1, Catalhoyuk West	ECII	1517	Einkorn
CW1T015	Trench 1, Catalhoyuk West	ECII	1490	Free-threshing wheat
CW1T013	Trench 1, Catalhoyuk West	ECII	1483	Hulled barley
CW1T023	Trench 1, Catalhoyuk West	ECII	1517	Lentil
CW1T017	Trench 1, Catalhoyuk West	ECII	1517	Pea

CW005	Trench 5, Catalhoyuk West	ECI	10289/9033	Einkorn
CW013	Trench 5, Catalhoyuk West	ECI	11090/11091	Einkorn
CW036	Trench 5, Catalhoyuk West	ECI	11008/11007	Einkorn
CW038	Trench 5, Catalhoyuk West	ECI	11089	Einkorn
CW039	Trench 5, Catalhoyuk West	ECI	11096	Einkorn
CW040	Trench 5, Catalhoyuk West	ECI	11097	Einkorn
CW032	Trench 5, Catalhoyuk West	ECI	9602	Emmer
CW004	Trench 5, Catalhoyuk West	ECI	10289/9033	Free-threshing wheat
CW015	Trench 5, Catalhoyuk West	ECI	11090/11091	Free-threshing wheat
CW020	Trench 5, Catalhoyuk West	ECI	11097	Free-threshing wheat
CW030	Trench 5, Catalhoyuk West	ECI	9573	Free-threshing wheat
CW033	Trench 5, Catalhoyuk West	ECI	9602	Free-threshing wheat
CW001	Trench 5, Catalhoyuk West	ECI	10110	Hulled barley
CW002	Trench 5, Catalhoyuk West	ECI	10111	Hulled barley
CW003	Trench 5, Catalhoyuk West	ECI	10289/9033	Hulled barley
CW006	Trench 5, Catalhoyuk West	ECI	11008/11007	Hulled barley
CW009	Trench 5, Catalhoyuk West	ECI	11041	Hulled barley
CW011	Trench 5, Catalhoyuk West	ECI	11088	Hulled barley
CW012	Trench 5, Catalhoyuk West	ECI	11090/11091	Hulled barley
CW016	Trench 5, Catalhoyuk West	ECI	11093	Hulled barley
CW017	Trench 5, Catalhoyuk West	ECI	11094	Hulled barley
CW018	Trench 5, Catalhoyuk West	ECI	11096	Hulled barley
CW019	Trench 5, Catalhoyuk West	ECI	11097	Hulled barley
CW021	Trench 5, Catalhoyuk West	ECI	8911	Hulled barley
CW023	Trench 5, Catalhoyuk West	ECI	9341	Hulled barley
CW024	Trench 5, Catalhoyuk West	ECI	9358	Hulled barley
CW025	Trench 5, Catalhoyuk West	ECI	9495	Hulled barley
CW026	Trench 5, Catalhoyuk West	ECI	9562	Hulled barley
CW027	Trench 5, Catalhoyuk West	ECI	9563	Hulled barley
CW028	Trench 5, Catalhoyuk West	ECI	9564	Hulled barley
CW031	Trench 5, Catalhoyuk West	ECI	9591	Hulled barley
CW035	Trench 5, Catalhoyuk West	ECI	10265	Hulled barley
CW008	Trench 5, Catalhoyuk West	ECI	11008/11007	Lentil
CW010	Trench 5, Catalhoyuk West	ECI	11041	Lentil
CW014	Trench 5, Catalhoyuk West	ECI	11090/11091	Lentil
CW034	Trench 5, Catalhoyuk West	ECI	9602	Lentil
CW037	Trench 5, Catalhoyuk West	ECI	11088	Lentil
CW022	Trench 5, Catalhoyuk West	ECI	8911	New type wheat
CW007	Trench 5, Catalhoyuk West	ECI	11008/11007	Pea
CW029	Trench 5, Catalhoyuk West	ECI	9564	Pea
CBT004	Çamlıbel Tarlası	CBTI	980	Bitter vetch

CBT007	Çamlıbel Tarlası	CBTI		1009 Bitter vetch
CBT018	Çamlıbel Tarlası	CBTI		843 Bitter vetch
CBT033	Çamlıbel Tarlası	CBTI		254 Bitter vetch
CBT059	Çamlıbel Tarlası	CBTI		394 Bitter vetch
CBT070	Çamlıbel Tarlası	CBTI		848 Bitter vetch
CBT077	Çamlıbel Tarlası	CBTI		306 Bitter vetch
CBT082	Çamlıbel Tarlası	CBTI	F394	Bitter vetch
CBT084	Çamlıbel Tarlası	CBTI	F395	Bitter vetch
CBT087	Çamlıbel Tarlası	CBTI	F390	Bitter vetch
CBT088	Çamlıbel Tarlası	CBTI		251 Bitter vetch
CBT097	Çamlıbel Tarlası	CBTI		313 Bitter vetch
CBT098	Çamlıbel Tarlası	CBTI	F387	Bitter vetch
CBT103	Çamlıbel Tarlası	CBTI	F390	Chickpea
CBT120	Çamlıbel Tarlası	CBTI		877 Chickpea
CBT016	Çamlıbel Tarlası	CBTI		907 Einkorn
CBT020	Çamlıbel Tarlası	CBTI		843 Einkorn
CBT042	Çamlıbel Tarlası	CBTI		254 Einkorn
CBT074	Çamlıbel Tarlası	CBTI		251 Einkorn
CBT079	Çamlıbel Tarlası	CBTI	F390	Einkorn
CBT086	Çamlıbel Tarlası	CBTI	F390	Einkorn
CBT094	Çamlıbel Tarlası	CBTI	F393	Einkorn
CBT095	Çamlıbel Tarlası	CBTI		850 Einkorn
CBT115	Çamlıbel Tarlası	CBTI		243 Einkorn
CBT119	Çamlıbel Tarlası	CBTI		313 Einkorn
CBT022	Çamlıbel Tarlası	CBTI		304 Emmer
CBT054	Çamlıbel Tarlası	CBTI		313 Emmer
CBT089	Çamlıbel Tarlası	CBTI		395 Emmer
CBT051	Çamlıbel Tarlası	CBTI		907 Free-threshing wheat
CBT101	Çamlıbel Tarlası	CBTI		877 Grass pea
CBT108	Çamlıbel Tarlası	CBTI		304 Grass pea
CBT109	Çamlıbel Tarlası	CBTI	F390	Grass pea
CBT121	Çamlıbel Tarlası	CBTI		843 Grass pea
CBT015	Çamlıbel Tarlası	CBTI		907 Hulled barley
CBT019	Çamlıbel Tarlası	CBTI		843 Hulled barley
CBT021	Çamlıbel Tarlası	CBTI		304 Hulled barley
CBT024	Çamlıbel Tarlası	CBTI		257 Hulled barley
CBT043	Çamlıbel Tarlası	CBTI		254 Hulled barley
CBT053	Çamlıbel Tarlası	CBTI		1009 Hulled barley
CBT060	Çamlıbel Tarlası	CBTI		54 Hulled barley
CBT065	Çamlıbel Tarlası	CBTI		313 Hulled barley
CBT073	Çamlıbel Tarlası	CBTI		850 Hulled barley

CBT076	Çamlıbel Tarlası	CBTI		246 Hulled barley
CBT078	Çamlıbel Tarlası	CBTI		208 Hulled barley
CBT085	Çamlıbel Tarlası	CBTI		877 Hulled barley
CBT090	Çamlıbel Tarlası	CBTI		243 Hulled barley
CBT091	Çamlıbel Tarlası	CBTI		251 Hulled barley
CBT092	Çamlıbel Tarlası	CBTI	F390	Hulled barley
CBT113	Çamlıbel Tarlası	CBTI	F393	Hulled barley
CBT003	Çamlıbel Tarlası	CBTI		980 Lentil
CBT017	Çamlıbel Tarlası	CBTI		907 Lentil
CBT023	Çamlıbel Tarlası	CBTI		304 Lentil
CBT025	Çamlıbel Tarlası	CBTI		257 Lentil
CBT034	Çamlıbel Tarlası	CBTI		254 Lentil
CBT063	Çamlıbel Tarlası	CBTI		843 Lentil
CBT069	Çamlıbel Tarlası	CBTI		848 Lentil
CBT075	Çamlıbel Tarlası	CBTI		246 Lentil
CBT080	Çamlıbel Tarlası	CBTI	F390	Lentil
CBT081	Çamlıbel Tarlası	CBTI	F392	Lentil
CBT083	Çamlıbel Tarlası	CBTI	F395	Lentil
CBT106	Çamlıbel Tarlası	CBTI		877 Lentil
CBT110	Çamlıbel Tarlası	CBTI		251 Lentil
CBT111	Çamlıbel Tarlası	CBTI		243 Lentil
CBT118	Çamlıbel Tarlası	CBTI		313 Lentil
CBT100	Çamlıbel Tarlası	CBTI		304 Pea
CBT014	Çamlıbel Tarlası	CBTI/II		97 Bitter vetch
CBT047	Çamlıbel Tarlası	CBTI/II		97 Hulled barley
CBT013	Çamlıbel Tarlası	CBTI/II		97 Lentil
CBT005	Çamlıbel Tarlası	CBTII		900 Bitter vetch
CBT028	Çamlıbel Tarlası	CBTII		1008 Bitter vetch
CBT039	Çamlıbel Tarlası	CBTII		895 Bitter vetch
CBT066	Çamlıbel Tarlası	CBTII		315 Bitter vetch
CBT041	Çamlıbel Tarlası	CBTII		895 Einkorn
CBT049	Çamlıbel Tarlası	CBTII		911 Einkorn
CBT071	Çamlıbel Tarlası	CBTII		315 Einkorn
CBT072	Çamlıbel Tarlası	CBTII		921 Einkorn
CBT112	Çamlıbel Tarlası	CBTII		325 Emmer
CBT105	Çamlıbel Tarlası	CBTII		1006 Grass pea
CBT006	Çamlıbel Tarlası	CBTII		902 Hulled barley
CBT029	Çamlıbel Tarlası	CBTII		1008 Hulled barley
CBT046	Çamlıbel Tarlası	CBTII		315 Hulled barley
CBT058	Çamlıbel Tarlası	CBTII		958 Hulled barley
CBT064	Çamlıbel Tarlası	CBTII		911 Hulled barley

CBT067	Çamlıbel Tarlası	CBTII	1006 Hulled barley
CBT001	Çamlıbel Tarlası	CBTII	939 Lentil
CBT030	Çamlıbel Tarlası	CBTII	1008 Lentil
CBT037	Çamlıbel Tarlası	CBTII	958 Lentil
CBT038	Çamlıbel Tarlası	CBTII	1006 Lentil
CBT040	Çamlıbel Tarlası	CBTII	895 Lentil
CBT061	Çamlıbel Tarlası	CBTII	911 Lentil
CBT062	Çamlıbel Tarlası	CBTII	315 Lentil
CBT027	Çamlıbel Tarlası	CBTIII	325 Bitter vetch
CBT036	Çamlıbel Tarlası	CBTIII	887 Bitter vetch
CBT052	Çamlıbel Tarlası	CBTIII	68 Bitter vetch
CBT056	Çamlıbel Tarlası	CBTIII	440 Bitter vetch
CBT099	Çamlıbel Tarlası	CBTIII	302 Bitter vetch
CBT102	Çamlıbel Tarlası	CBTIII	310 Bitter vetch
CBT026	Çamlıbel Tarlası	CBTIII	325 Einkorn
CBT114	Çamlıbel Tarlası	CBTIII	68 Einkorn
CBT107	Çamlıbel Tarlası	CBTIII	325 Grass pea
CBT008	Çamlıbel Tarlası	CBTIII	465 Hulled barley
CBT044	Çamlıbel Tarlası	CBTIII	887 Hulled barley
CBT050	Çamlıbel Tarlası	CBTIII	325 Hulled barley
CBT055	Çamlıbel Tarlası	CBTIII	68 Hulled barley
CBT057	Çamlıbel Tarlası	CBTIII	300 Hulled barley
CBT093	Çamlıbel Tarlası	CBTIII	310 Hulled barley
CBT009	Çamlıbel Tarlası	CBTIII	465 Lentil
CBT035	Çamlıbel Tarlası	CBTIII	887 Lentil
CBT048	Çamlıbel Tarlası	CBTIII	68 Lentil
CBT096	Çamlıbel Tarlası	CBTIII	325 Lentil
CBT104	Çamlıbel Tarlası	CBTIII	310 Lentil
CBT116	Çamlıbel Tarlası	CBTIII	466 Lentil
CBT117	Çamlıbel Tarlası	CBTIII	300 Lentil
CBT002	Çamlıbel Tarlası	CBTIV	133 Bitter vetch
CBT012	Çamlıbel Tarlası	CBTIV	152 Bitter vetch
CBT031	Çamlıbel Tarlası	CBTIV	146 Bitter vetch
CBT010	Çamlıbel Tarlası	CBTIV	152 Hulled barley
CBT045	Çamlıbel Tarlası	CBTIV	133 Hulled barley
CBT011	Çamlıbel Tarlası	CBTIV	152 Lentil
CBT032	Çamlıbel Tarlası	CBTIV	146 Lentil
CBT068	Çamlıbel Tarlası	CBTIV	147 Lentil

C ug (drift corrected)	%C	$\delta^{13}\text{C}$ (VPDB)	$\delta^{13}\text{C}_{\text{sd}}$	N ug (drift corrected)	%N	$\delta^{15}\text{N}$ (AIR)
413.0	61.6	-24.6	0.1	115.8	4.0	10.3
381.3	61.5	-23.5	0.1	121.4	4.1	10.8
421.3	62.0	-23.3	0.1	137.9	4.7	17.4
413.8	58.3	-21.8	0.1	152.6	5.3	5.4
444.0	64.4	-21.8	0.1	169.3	5.3	9.9
404.5	60.4	-23.0	0.1	190.9	6.1	10.2
334.3	49.2	-22.0	0.1	195.3	6.1	4.8
394.5	61.6	-22.9	0.1	153.8	5.2	8.9
412.0	60.6	-23.7	0.1	146.6	5.0	14.7
454.3	64.0	-23.3	0.1	130.7	4.5	9.4
448.0	64.9	-23.6	0.1	127.4	4.1	10.6
291.7	40.5	-24.0	0.1	98.6	3.3	9.4
393.1	56.2	-22.2	0.2	140.5	4.7	9.8
383.0	57.2	-22.5	0.1	155.2	5.1	8.4
459.1	65.6	-24.2	0.2	109.9	3.7	10.1
414.2	60.9	-24.5	0.0	124.0	4.3	8.5
455.1	68.9	-23.2	0.2	89.8	3.0	7.8
352.4	50.3	-23.4	0.2	105.6	3.6	7.4
371.7	58.1	-21.4	0.2	139.9	4.6	8.0
426.9	61.0	-25.0	0.2	99.8	3.1	10.3
365.3	55.4	-21.3	0.2	121.3	4.2	5.8
411.8	64.3	-23.4	0.2	114.3	4.0	13.3
385.7	59.3	-22.1	0.1	211.8	6.7	11.2
293.5	45.9	-22.9	0.1	155.1	5.3	13.2
333.2	49.0	-23.1	0.2	114.8	3.6	14.2
420.0	61.8	-22.3	0.1	134.8	4.3	12.8
411.2	59.6	-22.8	0.1	135.8	4.3	11.6
505.9	58.2	-22.8	0.1	113.7	7.4	4.4
487.8	58.1	-23.3	0.1	80.5	5.4	3.4
512.9	57.6	-23.2	0.2	96.2	6.0	3.4
407.0	59.9	-21.4	0.1	147.9	5.1	18.0
434.7	64.9	-22.3	0.1	154.8	5.3	13.3
359.9	52.9	-23.7	0.2	119.0	3.9	9.6
397.3	58.4	-22.0	0.1	170.2	5.5	10.2
403.4	58.5	-23.4	0.1	122.9	3.9	9.6
414.6	61.0	-22.8	0.2	99.6	3.4	10.6
495.1	59.6	-21.9	0.2	126.9	8.1	5.0
483.1	54.3	-23.2	0.2	105.3	6.9	3.8

468.8	68.9	-24.2	0.1	108.4	3.8	8.1
390.5	62.0	-22.8	0.1	146.8	4.6	8.5
308.2	48.9	-24.6	0.1	87.3	2.9	12.5
409.6	57.7	-22.4	0.1	128.3	4.2	9.4
331.4	51.8	-21.9	0.1	155.2	5.1	15.5
377.6	57.2	-24.6	0.1	89.1	3.1	9.1
448.7	66.0	-23.3	0.1	97.9	3.3	9.2
490.8	72.2	-23.3	0.1	119.5	4.0	9.1
416.0	58.6	-23.1	0.1	122.5	4.2	8.2
408.6	63.8	-23.5	0.1	114.8	3.7	8.7
419.3	61.7	-24.1	0.1	124.3	4.0	8.8
371.1	53.8	-22.4	0.1	135.4	4.3	9.0
719.8	105.9	-22.9	0.1	121.0	4.2	10.3
577.8	87.5	-22.9	0.1	143.2	4.8	11.9
491.5	75.6	-22.7	0.1	141.7	4.8	11.0
416.3	62.1	-21.9	0.1	151.1	4.8	9.5
421.7	65.9	-21.8	0.1	139.6	4.6	8.7
452.0	70.6	-24.2	0.0	85.7	3.0	7.7
423.8	67.3	-22.6	0.1	134.3	4.6	10.7
375.7	59.6	-22.9	0.1	108.8	3.7	10.2
378.6	61.1	-22.9	0.1	114.6	3.6	10.6
355.0	57.3	-22.5	0.1	139.4	4.6	11.2
387.6	62.5	-23.4	0.1	126.1	4.1	9.1
458.2	65.5	-23.2	0.1	127.3	4.1	11.0
402.8	57.5	-22.7	0.1	121.2	3.9	11.8
447.7	64.9	-22.7	0.1	227.0	7.7	18.9
408.4	61.9	-23.0	0.1	185.6	6.2	11.0
378.4	59.1	-23.0	0.1	122.6	4.2	12.2
378.2	57.3	-22.4	0.1	123.9	4.1	9.4
355.3	51.5	-22.2	0.1	127.3	4.3	11.9
381.5	56.9	-22.8	0.1	186.0	6.2	13.7
362.4	54.1	-22.5	0.1	115.0	4.0	13.3
597.8	72.9	-22.6	0.1	95.6	6.1	3.4
521.7	58.0	-23.3	0.1	73.9	5.0	3.2
442.8	52.1	-22.6	0.1	97.9	6.5	4.1
423.3	49.2	-21.9	0.1	93.5	6.2	5.8
411.4	48.4	-24.2	0.1	86.7	5.7	8.1
435.8	61.4	-23.6	0.1	119.5	3.9	8.4
498.8	60.8	-22.7	0.1	89.4	6.0	2.7
472.6	55.6	-23.3	0.1	80.5	5.4	5.9
453.8	56.7	-22.4	0.1	76	5.1	1.8

437.7	54	-22.5	0.1	103.6	6.6	3.5
465.1	56	-21.8	0.1	82.2	5.7	2.2
494.3	58.8	-22.8	0.3	77.3	5.3	1.7
518.1	56.3	-22.8	0.3	76.8	5	2
517	56.8	-22.1	0.4	82.8	5.1	1.5
429.1	53.6	-23.1	0.1	75.9	5.2	2.4
497.2	59.2	-23.8	0.1	36.4	2.5	1.6
509.8	57.9	-22.5	0.4	77.8	5	1.6
526.2	57.8	-22.9	0.4	94.8	6.2	2.1
505.9	57.5	-23.5	0.4	78.1	5.3	1.9
597.9	66.4	-24.1	0.4	83.2	5.5	2.5
487.5	57.4	-24.3	0.4	91.9	6.3	1.9
483.9	55.6	-23.2	0.1	95.4	6.2	2.1
471.8	51.3	-23.8	0.2	59.8	4	2.2
378.1	57.3	-22.8	0.1	109.9	3.6	5
335.2	52.4	-21.5	0.1	135.9	4.6	5.3
370.4	57	-21.7	0.4	115.6	3.9	3.1
412.7	63.5	-21.3	0.4	128.7	4.1	3.6
462.9	68.1	-22.9	0.4	115.9	4	5.2
377.5	53.2	-22.6	0.1	140.3	4.4	5.5
377.3	57.2	-21.3	0.4	113	3.7	3.9
329.4	47.7	-23.7	0.4	113.8	3.7	3.7
399.7	57.1	-22.2	0.1	106.7	3.5	4.1
338.9	50.6	-22.7	0.1	99.3	3.2	5.2
366.9	58.2	-23.1	0.1	102.1	3.5	5.9
319.7	50	-24.2	0.3	85.8	2.9	5.9
389.8	58.2	-21.7	0.4	102.2	3.5	5.3
369.8	59.6	-21.8	0.4	104.7	3.4	4.6
390.8	46.5	-22.6	0.1	80.2	5.1	3.2
440.1	54.3	-21.6	0.1	88.5	5.8	3
468.3	53.8	-21.6	0.1	90.1	5.7	3.3
459.1	51.6	-22.6	0.1	104.7	6.5	2.8
383.3	58.1	-23.5	0.1	78.7	2.5	4
356.7	53.2	-23.2	0.1	73.7	2.4	5.6
393.3	59.6	-23.8	0.1	86.5	2.9	5.2
454.9	65	-23.7	0.1	79.6	2.6	8.3
401.9	58.2	-23.1	0.3	74.2	2.5	4.4
393	56.1	-22.9	0.3	89.3	3	5.1
368.2	54.1	-21.3	0.4	92.8	3.1	7.8
350.8	56.6	-24.8	0.4	81.1	2.6	6.1
366	56.3	-22.7	0.4	89.6	2.9	3.7

401.8	60.9	-23.5	0.4	79.9	2.7	4.7
368	51.8	-23.4	0.4	224.8	7.4	6.1
383.4	59.9	-23.1	0.4	102.9	3.3	6.1
421.2	61	-23.6	0.4	74.3	2.5	4.9
429.3	60.5	-23.1	0.2	78.9	2.6	3.9
407.4	59.9	-21.8	0.4	102.5	3.2	5.2
406.6	58.9	-22.7	0.1	91.6	3.2	5.1
429.5	53	-22.8	0.1	104.4	6.9	2.6
473.9	53.3	-23.5	0.1	80.6	5.6	1.8
532.6	60.5	-21.4	0.1	80.4	5.3	3.2
514.9	62	-22.9	0.1	80.4	5.3	1.7
470.1	57.3	-23	0.3	82.7	5.3	2.4
470.4	56	-24.3	0.4	105.8	7	2.4
492.2	54.7	-22.4	0.4	102.7	6.5	3.1
436.3	53.2	-23.2	0.4	81.5	5.4	2.5
489.2	56.2	-23.5	0.4	103.5	6.6	3.4
502.6	62.1	-23.6	0.4	101.3	6.5	2.2
476.5	54.1	-22.3	0.1	79.4	5.2	2.1
399.9	44.9	-23.3	0.1	82.5	5.2	2.5
543.4	59.7	-22.1	0.1	84.7	5.8	3.1
532.4	57.9	-21.6	0.1	91.8	5.7	2.4
528.9	63	-22.9	0.1	86	5.9	2.3
529	58.8	-22.6	0.2	99.3	6.6	2.9
473.4	58.4	-23.6	0.1	78.2	5.1	1.3
392.2	55.2	-22.7	0.3	81	2.6	3.9
469.3	57.2	-22	0.1	86.9	5.7	2.3
472.7	55.6	-22.5	0.1	104.5	6.5	2.4
508.2	62.7	-22.5	0.1	79.9	5.6	2.1
529.4	60.2	-22.8	0.3	83.1	5.5	2.3
608.2	69.1	-23.3	0.4	87.3	5.9	2.2
396	57.4	-22.5	0.3	115.4	3.9	3.7
304.7	49.1	-23.4	0.3	193.4	6.6	2.5
375.1	58.6	-21.1	0.4	148.7	5.1	5.2
378.2	54	-24	0.4	232.3	8	4.7
375.7	56.9	-21.9	0.1	86.3	2.9	6.4
477.6	55.5	-21.5	0.1	86.4	5.5	2.8
366.1	55.5	-23.3	0.1	70.9	2.5	4.4
387.5	57.8	-24	0.3	99.3	3.4	5.1
378.5	56.5	-22.4	0.3	144.2	4.9	3.6
336.9	53.5	-22.6	0.3	74.8	2.6	3.5
389.6	58.2	-24.6	0.4	194.2	6.6	1.7

389.8	62.9	-23.2	0.4	75.3	2.5	3.6
487.6	59.5	-22.2	0.1	89.3	5.8	2.8
429.4	50.5	-24.8	0.3	82.7	5.6	2.9
465.4	56.1	-21.4	0.4	93.2	6.4	2.8
511.5	58.1	-23.4	0.3	86.3	5.6	2.5
469	58.6	-22.8	0.3	90.5	6.1	3
387.3	42.6	-22.2	0.4	112.3	7	2.9
459.1	56.7	-24	0.4	111.3	7.6	3.1
539	64.2	-21.9	0.1	72.1	4.7	2.2
555.7	61.7	-23.8	0.3	83.5	5.8	2.4
519.4	57.1	-22.2	0.3	79	5.4	1.6
507.3	55.1	-24.9	0.3	84	5.7	2
509.9	57.9	-23.7	0.4	79.9	5.3	2.9
551.5	59.9	-24.1	0.1	73.8	4.9	2.7
402.6	58.4	-22.6	0.1	101.2	3.5	5.2
378.2	53.3	-22.4	0.1	123.5	4.1	6.5
459.1	54	-22.2	0.1	82.7	5.3	2.4
369.7	53.6	-22.5	0.1	93.4	3.1	5.2
370.8	58.9	-24.1	0.3	74.3	2.5	3.4
373.6	54.1	-25	0.3	66.3	2.2	4.9
409	60.2	-24.7	0.3	71.6	2.4	6.2
333.2	53.7	-22.8	0.3	77.5	2.5	4.2
413.7	58.3	-25.4	0.4	81.6	2.6	3.9
479.5	55.8	-22.5	0.1	92.1	6	3.1
484	59	-23.2	0.3	92.1	6.3	2.3
511	55.5	-22.8	0.3	88.7	5.5	2.6
463.5	55.8	-23.3	0.4	88.6	5.9	2.8
463.6	55.2	-22.5	0.1	107.6	7.1	2.9
537.8	57.8	-22.4	0.1	91.8	6.4	2.2
456.2	55	-22.4	0.1	89.3	5.9	2.5
471.8	58.3	-22.7	0.1	81.9	5.4	2
498.7	55.4	-23	0.1	79.3	5.1	2.7
454.5	55.4	-23	0.3	74.3	4.8	1.9
381.1	56	-22.7	0.1	85.4	2.9	5.5
441.8	62.2	-24.3	0.3	67.4	2.3	3.8
516.6	60.1	-22.3	0.1	80.7	5.1	2.2
503.2	57.8	-23.2	0.3	87.8	5.8	2.2
529.5	59.5	-22.4	0.4	90.4	6.1	2.5

$\delta^{15}\text{N}_{\text{sd}}$	$\delta^{15}\text{N}$ (adjusted for charring by - 0.31)	$\delta^{13}\text{C}$ (adjusted for charrin by - 0.11)	C:N	$\Delta^{13}\text{C}$ (calculated from adjusted $\delta^{13}\text{C}$ value)	
	0.3	9.9	-24.8	18.1	18.6
	0.3	10.5	-23.6	17.4	17.4
	0.3	17.0	-23.4	15.4	17.2
	0.0	5.1	-21.9	12.9	15.6
	0.2	9.6	-21.9	14.2	15.6
	0.3	9.9	-23.1	11.5	16.8
	0.0	4.5	-22.2	9.4	15.8
	0.2	8.6	-23.0	13.7	16.7
	0.0	14.4	-23.8	14.2	17.5
	0.2	9.1	-23.4	16.6	17.1
	0.2	10.3	-23.7	18.7	17.4
	0.3	9.1	-24.1	14.2	17.9
	0.4	9.5	-22.3	13.8	16.0
	0.4	8.1	-22.6	13.1	16.3
	0.4	9.7	-24.3	20.8	18.1
	0.4	8.2	-24.6	16.6	18.4
	0.4	7.5	-23.3	26.4	17.1
	0.4	7.1	-23.5	16.1	17.2
	0.4	7.7	-21.6	14.8	15.2
	0.4	10.0	-25.1	22.8	18.9
	0.0	5.5	-21.4	15.5	15.1
	0.4	13.0	-23.5	19.0	17.3
	0.4	10.9	-22.2	10.4	15.9
	0.4	12.9	-23.0	10.0	16.7
	0.4	13.9	-23.2	15.9	16.9
	0.4	12.5	-22.4	16.6	16.1
	0.4	11.3	-22.9	16.2	16.7
	0.4	4.1	-22.9	9.2	16.6
	0.4	3.1	-23.4	12.5	17.1
	0.4	3.1	-23.3	11.1	17.0
	0.0	17.7	-21.5	13.8	15.2
	0.4	13.0	-22.4	14.2	16.1
	0.4	9.3	-23.8	15.7	17.6
	0.4	9.9	-22.1	12.3	15.8
	0.4	9.3	-23.5	17.4	17.3
	0.4	10.3	-22.9	20.8	16.7
	0.4	4.7	-22.0	8.6	15.7
	0.4	3.5	-23.3	9.1	17.1

0.2	7.8	-24.3	21.4	18.1
0.2	8.2	-23.0	15.6	16.7
0.3	12.2	-24.7	20.0	18.5
0.3	9.1	-22.5	15.9	16.3
0.3	15.2	-22.0	11.8	15.7
0.3	8.8	-24.8	21.8	18.6
0.2	8.9	-23.5	23.0	17.2
0.2	8.8	-23.4	20.9	17.2
0.2	7.9	-23.2	16.2	16.9
0.2	8.4	-23.7	19.9	17.4
0.2	8.5	-24.3	17.9	18.0
0.2	8.7	-22.5	14.7	16.2
0.2	10.0	-23.0	29.7	16.7
0.2	11.6	-23.0	21.3	16.8
0.2	10.6	-22.8	18.3	16.5
0.2	9.2	-22.0	15.0	15.7
0.2	8.4	-21.9	16.6	15.6
0.0	7.4	-24.3	27.8	18.2
0.2	10.4	-22.7	17.1	16.4
0.2	9.9	-23.0	18.6	16.8
0.2	10.3	-23.0	19.6	16.7
0.2	10.9	-22.6	14.4	16.3
0.2	8.7	-23.5	17.8	17.3
0.2	10.7	-23.3	18.8	17.0
0.2	11.5	-22.8	17.1	16.5
0.0	18.5	-22.8	9.9	16.5
0.2	10.7	-23.1	11.6	16.9
0.2	11.9	-23.1	16.3	16.8
0.2	9.1	-22.5	16.4	16.3
0.2	11.6	-22.3	14.0	16.0
0.2	13.4	-22.9	10.8	16.7
0.3	13.0	-22.7	15.9	16.4
0.2	3.1	-22.7	14.1	16.4
0.2	2.9	-23.5	13.5	17.2
0.2	3.7	-22.7	9.4	16.4
0.2	5.4	-22.0	9.3	15.7
0.3	7.8	-24.3	10.0	18.1
0.2	8.1	-23.7	18.2	17.4
0.2	2.4	-22.8	11.9	16.5
0.2	5.6	-23.4	12.1	17.2
0.2	1.5	-22.5	13	16.5

0.2	2.4	-22.6	9.6	16.6
0.2	1.9	-21.9	11.5	15.9
0.4	1.4	-22.9	13	16.9
0.4	1.7	-22.9	13.3	16.9
0.3	1.2	-22.2	12.9	16.1
0.3	2.1	-23.2	12	17.2
0.4	1.3	-23.9	27.9	18
0.3	1.3	-22.7	13.6	16.6
0.3	1.8	-23	10.8	17
0.3	1.6	-23.6	12.7	17.7
0.3	2.2	-24.3	14.1	18.3
0.3	1.6	-24.5	10.7	18.5
0.3	1.8	-23.4	10.5	17.4
0.3	1.9	-23.9	14.8	17.9
0.2	4.7	-22.9	18.6	16.9
0.2	5	-21.6	13.3	15.5
0.4	2.8	-21.8	17	15.8
0.3	3.3	-21.4	17.9	15.3
0.3	4.9	-23	19.9	17
0.3	5.2	-22.7	14.1	16.7
0.4	3.6	-21.4	18.2	15.4
0.3	3.4	-23.8	15.2	17.8
0.3	3.8	-22.3	19.3	16.2
0.3	4.9	-22.8	18.2	16.8
0.2	5.6	-23.2	19.6	17.2
0.4	5.6	-24.3	20	18.3
0.3	5	-21.8	19.6	15.7
0.4	4.2	-21.9	20.4	15.8
0.3	2.9	-22.7	10.6	16.7
0.3	2.6	-21.7	11	15.6
0.3	3	-21.7	11.1	15.7
0.3	2.5	-22.7	9.2	16.7
0.2	3.7	-23.6	27.2	17.6
0.2	5.3	-23.3	25.4	17.3
0.2	4.8	-23.9	24	17.9
0.2	7.9	-23.8	29.5	17.8
0.4	4.1	-23.2	26.9	17.2
0.4	4.8	-23	21.5	17
0.3	7.3	-21.4	20.7	15.3
0.3	5.8	-24.9	25.6	19
0.3	3.4	-22.8	22.9	16.8

0.3	4.4	-23.6	26.2	17.6
0.3	5.7	-23.5	8.2	17.5
0.3	5.8	-23.2	21.3	17.2
0.3	4.6	-23.7	28.3	17.7
0.3	3.6	-23.2	27.3	17.2
0.3	4.9	-21.9	21.6	15.9
0.3	4.8	-22.9	21.8	16.8
0.2	2.3	-22.9	8.9	16.9
0.2	1.5	-23.6	11.1	17.7
0.2	2.9	-21.5	13.3	15.4
0.2	1.4	-23	13.6	17
0.4	2.1	-23.1	12.7	17.1
0.3	2.1	-24.4	9.3	18.5
0.3	2.7	-22.5	9.8	16.5
0.3	2.2	-23.3	11.4	17.3
0.3	3.1	-23.6	9.9	17.6
0.3	1.9	-23.8	11.1	17.8
0.4	1.8	-22.4	12.3	16.4
0.3	2.2	-23.5	10	17.5
0.3	2.8	-22.2	12.1	16.2
0.3	2.1	-21.7	11.8	15.7
0.3	1.9	-23	12.5	17
0.3	2.6	-22.7	10.4	16.7
0.2	0.9	-23.7	13.3	17.8
0.4	3.6	-22.8	24.8	16.8
0.2	2	-22.1	11.8	16
0.2	2.1	-22.7	9.9	16.6
0.2	1.8	-22.6	13.2	16.5
0.4	2	-22.9	12.7	16.9
0.3	1.9	-23.4	13.7	17.4
0.4	3.4	-22.6	17.3	16.6
0.4	2.2	-23.6	8.7	17.6
0.3	4.9	-21.2	13.5	15.1
0.4	4.4	-24.2	7.9	18.2
0.3	6.1	-22	23.2	16
0.3	2.5	-21.6	11.9	15.5
0.2	4.1	-23.4	26.3	17.4
0.4	4.8	-24.1	19.8	18.2
0.4	3.3	-22.5	13.5	16.5
0.4	3.2	-22.7	24.3	16.7
0.3	1.4	-24.7	10.3	18.7

0.4	3.3	-23.3	29.6	17.4
0.2	2.5	-22.4	12	16.3
0.4	2.6	-24.9	10.5	19
0.4	2.5	-21.5	10.2	15.4
0.4	2.2	-23.5	12.1	17.6
0.4	2.7	-22.9	11.2	16.9
0.4	2.6	-22.4	7.1	16.3
0.3	2.8	-24.1	8.7	18.2
0.2	1.9	-22	16	16
0.4	2	-23.9	12.5	17.9
0.4	1.3	-22.3	12.3	16.2
0.4	1.7	-25	11.3	19.1
0.3	2.6	-23.8	12.7	17.9
0.3	2.4	-24.2	14.4	18.2
0.2	4.9	-22.7	19.7	16.7
0.3	6.2	-22.5	15.1	16.5
0.3	2.1	-22.3	11.9	16.3
0.2	4.9	-22.7	19.9	16.6
0.4	3.1	-24.2	27	18.3
0.4	4.6	-25.1	28.1	19.2
0.4	5.9	-24.8	28.8	18.9
0.4	3.8	-22.9	25.3	16.9
0.3	3.5	-25.5	26	19.6
0.2	2.8	-22.6	10.9	16.6
0.4	2	-23.3	10.8	17.3
0.4	2.2	-22.9	11.7	16.9
0.3	2.5	-23.5	11	17.5
0.3	2.6	-22.6	9.1	16.6
0.3	1.9	-22.5	10.6	16.5
0.3	2.2	-22.5	10.9	16.5
0.2	1.6	-22.8	12.7	16.8
0.2	2.4	-23.1	12.6	17.1
0.4	1.6	-23.1	13.4	17.2
0.2	5.2	-22.8	22.7	16.8
0.4	3.5	-24.4	31.7	18.4
0.2	1.9	-22.4	13.6	16.4
0.4	1.8	-23.3	11.6	17.3
0.3	2.2	-22.5	11.4	16.4

Site	Phase	Species	Number	$\delta^{15}\text{N}$ mean	$\delta^{15}\text{N}$ SD
Catalhoyuk	All	Einkorn	14	10.5941414	2.89719989
Catalhoyuk	All	Emmer	5	10.4254213	3.86126894
Catalhoyuk	All	Free-threshing wheat	10	8.18959089	1.24700594
Catalhoyuk	All	Hulled barley	31	10.7037768	2.58284192
Catalhoyuk	All	New type wheat	6	9.92190311	2.32954969
Catalhoyuk	All	Pea	4	3.65526112	1.39311521
Catalhoyuk	All	Lentil	8	4.36097803	1.64024234
Çamlıbel Tarlası	All	Einkorn	16	4.225	1.04721854
Çamlıbel Tarlası	All	Emmer	4	5.575	0.45
Çamlıbel Tarlası	All	Free-threshing wheat	1	4.2	
Çamlıbel Tarlası	All	Hulled barley	31	4.48709677	1.29659604
Çamlıbel Tarlası	All	Lentil	33	2.27272727	0.41023829
Çamlıbel Tarlası	All	Pea	1	2.6	
Çamlıbel Tarlası	All	Bitter vetch	27	1.78518519	0.41667521
Çamlıbel Tarlası	All	Chickpea	2	1.85	0.07071068
Çamlıbel Tarlası	All	Grass pea	6	2.6	0.32249031

$\delta^{13}\text{C}$ mean	$\delta^{13}\text{C}$ SD	$\Delta^{13}\text{C}$ mean	$\Delta^{13}\text{C}$ SD
-23.227225	1.17047328	16.9625427	1.21886442
-23.677858	0.50904487	17.4412238	0.55354736
-23.204376	1.12471983	16.9386114	1.17063836
-22.795576	0.53636964	16.5176175	0.57385479
-23.612676	0.37816648	17.3627817	0.39399847
-23.208883	0.29838196	16.9421614	0.31056204
-22.941756	0.78012612	16.6646257	0.8119955
-22.53125	0.88748239	16.50625	0.91540064
-22.825	1.16153634	16.8	0
-21.9		15.8	
-23.477419	0.92473768	17.4903226	0.96517868
-22.921212	0.77852327	16.9181818	0.82365593
-22.7		16.7	
-23.174074	0.78573464	17.1777778	0.8238434
-23.65	0.35355339	17.65	0.35355339
-22.116667	0.51542862	16.0833333	0.55287129

Elizabeth Stroud: Conceptualization, Investigation, Formal analysis, Software, Data Curation, Writing- Original Draft, Writing - Review & Editing, Visualization, Funding acquisition.

Michael Charles: Supervision, Writing - Review & Editing.

Amy Bogaard: Supervision, Funding acquisition, Writing - Review & Editing.