

# Landscape transformations at the dawn of agriculture in southern Syria (10.7–9.9 ka cal. BP): plant-specific responses to the impact of human activities and climate change

Article

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#### 35 Abstract

In southwest Asia, the accelerated impact of human activities on the landscape has often 36 been linked to the development of fully agricultural societies during the middle and late 37 Pre-Pottery Neolithic B (PPNB) period (around 10.2-7.9 ka cal. BP). This work 38 contributes to the debate on the environmental impact of the so-called Neolitisation 39 process by identifying the climatic and anthropogenic factors that contributed to change 40 local and regional vegetation at the time when domesticated plants appear and developed 41 in southern Syria (around 10.7-9.9 ka cal. BP). In this work an inter-disciplinary analyses 42 43 of botanical microremains (pollen and phytoliths) and macroremains (wood charcoal) is carried out along with stable carbon isotope discrimination of wood charcoals in an early 44 PPNB site (Tell Qarassa North, west of the Jabal al-Arab area). Prior to 10.5 ka cal. BP, 45 the results indicate a dynamic equilibrium in the local and regional vegetation, which 46 comprised woodland-steppe, Mediterranean evergreen oak-woodlands, wetland vegetation 47 and coniferous forests. Around 10.5-9.9 ka cal. BP, the elements that regulated the 48 vegetation system changed, resulting in reduced proportions of arboreal cover and the 49 spread of cold-tolerant and wetlands species. Our data show that a reinforcing interactions 50 between the elements of the anthropogenic (e.g. herding, fire-related activities) and 51 52 climatic systems (e.g. temperature, rainfall) contributed to the transformation of early Holocene vegetation during the emergence of fully agricultural societies in southern Syria. 53

54

# 55 Keywords

Palaeovegetation; Early Holocene; Climate change; Southwest Asia; Domestication;
Archaeobotany; Anthropogenic impact

58

#### 59 Highlights

- Multi-proxy analyses reveal diverse vegetation around 10.7-9.9 ka cal. BP.
- Cereals were domesticated in wetter conditions than at present in southern Syria.
- Dynamic equilibrium around 10.7-10.5 ka cal. BP, changes around 10.5-9.9 ka cal.
  BP.
- RCCs as trigger for the expansion of cold-tolerant and wetland vegetation.
- Increased anthropogenic impacts and RCCs coincided with decreased arboreal
   cover.

67

# 68 **1. Introduction**

The Pre-Pottery Neolithic (PPN) represents a key time period to understand the 69 emergence of agriculture in southwest Asia. During the Pre-Pottery Neolithic A (PPNA, 70 11.6-10.7 ka cal. BP), there is evidence for the development of plant food production 71 72 activities involving morphologically wild plant species (Willcox et al., 2008), along with the evidence of early control or management of wild animal populations (Ervynck et al., 73 74 2001; Vigne, 2013). Subsequently, during the early Pre-Pottery Neolithic B (EPPNB, 10.7-75 10.2 ka cal. BP), the first morphologically domesticated plants (Tanno and Willcox, 2012) 76 and animal species (Helmer et al., 2005; Peters et al. 2005; Zeder, 2011) appear in the 77 archaeological record, yet the exploitation of morphologically wild species predominated during this time. Agriculture, defined as a subsistence system largely relying on 78 domesticated resources (Zeder, 2015), evolved only around 10.2-9 ka cal. BP, during the 79 middle and late PPNB (Asouti and Fuller, 2012, 2013; Zeder, 2011). 80

The environmental settings of the PPN period, exception made for the Khiamian period 81 that developed within the last years of the Younger Dryas, were primarily those of the Pre-82 boreal climatic oscillations (Maher et al., 2011). This period was characterised by rapid 83 84 warming, with increased mean yearly temperatures of about 7°C (Alley, 2000), combined 85 with minimum rainfall rates in excess of 350 mm/yr, making it one of the wettest periods in Southwest Asia in the last 25,000 years (Robinson et al., 2006; Weninger et al., 2009). 86 87 However, early Holocene climate was not stable, and several Rapid Climatic Changes (RCCs) occurred in the eastern Mediterranean at the time when agriculture developed in 88 89 southwest Asia, c. 10.2 ka cal. BP (Mayewski et al., 2004; Weninger et al., 2009). Such RCCs comprised cold/dry (e.g. 10.2 and 8.2 ka cal. BP) and wet/warm (Levantine Moist 90 91 Period and Sapropel S1, 10.1-8.6 ka cal. BP) spells. Some of these events seem to have 92 caused considerable changes in the vegetation. For example, maximum Pistacia 93 percentages (the so-called "Pistacia Phase") were recorded during the Sapropel depositions (around 9-6 ka cal. BP) in several pollen diagrams from the Adriatic and 94 Ionian Sea, Lake Ioannina and Lake Xinias (Greece), Tenaghi Phillippon (Greece), and 95 Ghab (Syria) indicating relatively warm winters and mild summers (Rossignol-Strick 96 1995; 1999). Reductions in the proportions of evergreen Quercus were recorded shortly 97 after the dry 8.2 ka cal. BP event at Tenaghi Phillippon Greece (Pross et al., 2009). During 98 99 the same time period in the Eastern Mediterranean (close to the Israel coast) pollen records 100 from deep-sea cores indicate maximum values for dry-tolerant Artemisia (Laggunt et al., 2011). Yet, the understanding of the effects that early Holocene RCCs caused in the 101

vegetation, and by extension, in the subsistence of the early agricultural groups during the
Pre-Pottery Neolithic is still limited (Weninger et al., 2009; Flhor et al., 2016; Berger et
al., 2016).

105 Despite the diverse bioclimatic regions and vegetation zones in southwest Asia (see a 106 short summary in Asouti et al., 2015), the available pollen records indicate a consistent 107 reduction in non-arboreal pollen (NAP) during the early Holocene, and an overall increase 108 in arboreal pollen (AP), characterised, in particular, by the spread of woodland-steppe taxa 109 (Pistacia and Amygdalus, pistachio and almond) and Quercus (oak) woodlands (van Zeist 110 and Bottema, 1977; van Zeist and Woldring, 1978; Rossignol-Strick, 1993, 1995, 1997, 1999; Stevens et al., 2001, 2006; Wright and Thorpe, 2003; Wick et al., 2003; Rosen, 111 2007; Hajar et al., 2010; Rambeau, 2010). However, the time at which oak-woodlands 112 113 developed across southwest Asia varied from one region to the other. In the Mediterranean area of the western Levant the spread of deciduous Quercus occurred 10.3-8.4 ka cal. BP 114 (Wright and Thorpe, 2003; Rosen, 2007; van Zeist et al., 2009), whereas pollen records 115 116 from the Irano-Anatolian region including southwest Iran (Zagros area) and central and eastern Anatolia point to a later expansion, around 7.5-4.5 ka cal. BP (Bottema and 117 118 Woldring, 1984; van Zeist and Bottema, 1977; Stevens et al., 2001; Wick et al., 2003; 119 Djamali et al., 2008; Litt et al., 2009).

Some argued that climatic conditions that would have allowed oak-woodland expansion 120 121 did not develop in these areas until later (van Zeist and Bottema, 1991; Roberts and Wright, 1993; Rossignol-Strick, 1997). Yet, others have attributed this delay to 122 123 anthropogenic factors. Several researchers proposed that increased wildfires at the beginning of the Holocene could have contributed to the development of grasslands in 124 125 central and eastern Anatolia (considered as competitors for oak-seedlings), which would 126 have hindered oak growth and expansion (Wick et al., 2003; Turner et al., 2010). Roberts 127 (2002) suggested that the human activities that developed with the establishment of agriculture in southwest Asia (e.g. land clearance for crop cultivation, burning, animal 128 grazing/browsing, and wood cutting for fuel and lime-plaster manufacture), besides a more 129 130 marked seasonality and the intensified occurrence of wild fires during the early Holocene, were overall responsible for the late establishment of oak-woodlands in central-eastern 131 132 Anatolia and the Zagros (see also Turner et al., 2010). Based on wood charcoal analyses, 133 pollen records and observations on modern vegetation in central Anatolia, Asouti and 134 Kabukcu (2014) suggested that semi-arid deciduous oak woodlands in this particular region evolved progressively, for around 3000 years, enhanced by several anthropogenic 135

activities (i.e. selective exploitation of Rosaceae-Maloideae, light-moderate grazing by
ruminants and managements of *Quercus* stands) carried out by M/LPPNB groups starting
around 9-8 ka cal. BP. They argued that early Neolithic anthropogenic activities
contributed to, rather than hampered, the spread of oak-woodland vegetation in the IranoAnatolian region, and they considered these low-diversity oak-dominated woodlands as
one of the earliest anthropogenic vegetation types in southwest Asia.

142 Nevertheless, the type and scale of the impacts caused by human groups around 10.0 ka cal. BP in southwest Asia was regionally diverse, probably as a consequence of the 143 144 different environmental conditions and economic activities carried out by local human 145 populations. In the Zagros area, increased proportions of Plantago lanceolata (English 146 plantain) in the pollen records has been interpreted as evidence of highly disturbed habitats 147 caused by fires set by local hunters and herders (van Zeist and Bottema, 1977; see also Wasylikowa et al., 2006). In the northern Levant (Ghab area, northwest Syria), Yasuda et 148 al. (2000) recorded an increase of micro-charcoals and the decline of Quercus pollen 149 around 10.1-9.5 ka cal. BP, interpreting it as the oldest evidence of large-scale 150 151 anthropogenic forest clearance or deforestation (see Roberts, 2002 and Meadows, 2005, 152 for an alternative interpretation of the data). In the southern Levant, several authors 153 claimed that agricultural and lime production activities by PPNB groups in areas that 154 nowadays receive low average rainfall for dry-farming (i.e. marginal areas) completely 155 modified the pre-existing landscape and could have led to deforestation (Köhler-Rollefson 1988, Bar-Yosef, 1995; Rollefson 1990, Köhler-Rollefson and Rollefson, 1989, 1990). 156 157 Yet, authors such as Blumler (2007) have put into questions that deforestation occurred during the early Holocene in Southwest Asia, since the re-examination of 13 primary 158 159 pollen datasets from Greece, Turkey, Syria and Israel do not show strong reduction in arboreal cover during this time (e.g. from 90% to 30%). This view is reinforced by pollen 160 161 records in north-western Turkey and Northern Israel (Golan Heights), where 162 anthropogenic activities (e.g. herding) were identified only during the Early Bronze Age (ca. 4.8 ka cal. BP) (Miebach et al. 2015; Schwab et al. 2004), and slightly later, around 163 164 3.8 ka cal. BP, in the Lake Van (eastern Anatolia) (Wick et al., 2003). Asouti et al. (2015) proposed that far from causing degradation, anthropogenic activities could have enhanced 165 166 woodland-expansion not only in the Irano-Anatolian region but also in the arid area of the southern Levant (e.g. Jordan Rift Valley). High proportions of Pistacia wood charcoal and 167 168 nutshells found at Pre-Pottery Neolithic Wadi el-Hemmeh were interpreted as evidence for the intensive management of these trees as a source of food, fuel and fodder, and along 169

with early Holocene climatic improvements, they would have contributed to the gradual
expansion of *Pistacia* woodlands in the area (Asouti et al., 2015).

All perspectives considered, the degree to which early Holocene climate and Neolithic 172 173 activities shaped local and regional vegetation in southwest Asia remains still an open 174 question. There are as yet no enough data to address the effects of early Holocene RCC in the vegetation across southwest Asia, and depending on the author and the region under 175 176 study, there are multiple views regarding the impact of Neolithic activities in the landscape (e.g. severe impacts in the form of deforestation, contribution to woodland expansion, no 177 178 impact in the landscape until later periods). In addition to this, most of the studies so far 179 have focused on the anthropogenic impacts of fully-fledged agricultural societies in southwest Asia (i.e. 10.2 ka cal. BP onwards), and as a result, there is a significant lack of 180 181 evidence to characterise the environmental setting and anthropogenic impacts that concern 182 the period immediately preceding the emergence of agriculture (e.g. the PPNA and EPPNB, around 11.6-10.2 ka cal. BP), despite animal and plant management activities 183 184 were already common practice during this time.

185

#### 186 **2.** Aims and scope

187 In this study we focus on the local and regional setting of Tell Qarassa North, an EPPNB site located in southern Syria (west of the Jabal al-Arab area). The site was 188 occupied around 10.7-9.9 ka cal. BP (Ibañez et al., 2010), the time at which 189 190 morphologically domesticated plants first appear in southwest Asia (Tanno and Willcox, 191 2012; Arranz-Otaegui et al., 2016a). Tell Qarassa provides direct evidence from plant micro and macroremains found in archaeological context, correlated by micro and 192 193 macrostratigraphic studies and radiocarbon dating (Ibañez et al., 2010b; Balbo et al., 2012; 194 Santana et al., 2012, 2015; Arranz-Otaegui et al., 2016a). The aim of this work is twofold: 195 (i) to use the high-resolution datasets from Tell Qarassa North to reconstruct the complex dynamics of the local and regional vegetation and environmental conditions around 10.7-196 197 9.9 ka cal. BP, tracing the evolution of different plant formations at the time when morphologically domesticated cereals appeared and developed in southern Syria; and (ii) 198 to explore the factors that regulate the evolution of plant formations over time considering 199 200 that changes in the vegetation occur as a result of the complex interaction patterns between 201 the vegetation system and others systems (e.g. climate). To address these issues we carry 202 out, for the first time, an inter-disciplinary study combining pollen, opal phytoliths, wood 203 charcoal remains and stable carbon isotope signature of wood charcoals from archaeological contexts. This work constitutes a substantial contribution to the
understanding of environmental conditions at the time of cereal domestication in southern
Syria and the climatic and anthropogenic factors that shaped past vegetation prior and
during the development of agriculture in southwest Asia.

208

# 209 3. Tell Qarassa North and its current environmental context

210 The site of Tell Qarassa North was excavated in 2009 and 2010 by a Spanish team (Ibáñez et al., 2009, 2010a, 2010b) as part of the Syrian-French-Spanish archaeological 211 212 research project around the palaeo-lake of Qarassa (Braemer et al., 2007, 2011). The site is 213 located 25 km to the west of the Jabal al-Arab mountain range (36°49'54''N-41°27'40''E, 750 m a.s.l.) and 20 km from the city of Sweida, south Syria (Figure 1a). The early PPNB 214 215 levels of Tell Qarassa North comprise square shaped wood-made and stone-made architecture (Ibañez et al., 2009; Balbo et al., 2012), ground stone tools such as saddle 216 querns and mortars, imported materials such as obsidian (Ibañez et al., 2009), diverse 217 funerary customs (Santana et al., 2012, 2015), anthropogenic figurines (Ibañez et al., 218 2014), as well as faunal remains including primarily goat (L. Gourichon in Ibañez et al., 219 220 2010a). Tell Qarassa North is one of the two sites in the southern-central Levant (along 221 with Tell Aswad, Tanno and Willcox, 2012) that has provided evidence for the presence of 222 morphologically domesticated-type cereals (Arranz-Otaegui et al., 2016a).

223 Present-day climate in the Jabal al-Arab comprise cold winters (average temperature of -2 °C, and snow accumulations in some areas) and hot summers (mean temperatures of 224 225 around 29 C°). The area where Tell Qarassa North is located receives a mean annual precipitation of around 350 mm (Chikhali and Amri, 2000; Traboulsi, 2013), and it is 226 227 characterized by a large basaltic field with many locally interconnected multilayer aquifers 228 that act as water conduits at different depths, allowing the formation of numerous springs, 229 water ponds and lakes (Braemer et al., 2009; E. Iriarte and A. Balbo in Ibáñez et al., 2010a). Tell Qarassa is located in the southern border of a Pleistocene lava field, which is 230 characterised by very scarce soil cover (Figure 1b). To the south of the tell Pliocene 231 232 basaltic materials are found, which provide rich soils to carry out agricultural activities. To the east of the site, there is evidence of an ancient lake (dated broadly from the late 233 Pleistocene to the mid-Holocene) and towards the south a temporary river is found 234 235 (Braemer et al., 2009; E. Iriarte and A. Balbo in Ibañez et al., 2009, 2010a).

236

Figure 1. A) Location of Tell Qarassa North in southwest Asia and B) detail of the surrounding area, including the paleolake (in blue) and the Leja Basaltic plain to the north (in yellow). B) Stratigraphy profiles of excavation areas XYZ and VU at Tell Qarassa North showing site phases and chronology. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article)



242 243

The Jabal al-Arab is considered a Mediterranean island within the Irano-Turanian region (Chikhali and Amri, 2000). The current vegetation in the area is rich and diverse with at least 900 species and various endemic taxa. Three main plant communities characterize the study area (Mouterde, 1953): a) to the north (Leja area), a degraded woodland-steppe community of *Pistacia atlantica* (Persian turpentine tree) and *Amygdalus* 

249 korschinskii (wild almond) is dominant; b) in the central area of the Jabal al-Arab, with altitudes reaching 1000-1500 m a.s.l., an open-woodland community of Quercus 250 calliprinos (Palestine oak) and Crataegus azarolus (hawthorn) grows, along with Pyrus 251 252 syriaca (Syrian pear), Pistacia atlantica, Acer microphyllum (small leaf maple) and Crataegus sinaica (Sinai hawthorn), the latter indicating the influence of altitude and 253 dryness; in addition, Quercus ithaburensis (Mount Thabor's oak) has also been attested in 254 255 this area (Willcox, 1999); and, c) to the east of the uplands, at an altitude around 700 m a.s.l., with a mean annual rainfall of 80-100 mm, dry-steppe vegetation dominated by 256 257 Artemisia (wormwood) and some Chenopodiaceae (goosefoot) extends.

258

# 259 4. Materials and Methods

260 The plant macro-remains and micro-remains analysed in this work come from Tell 261 Qarassa North, Zone 1, which comprises two excavation areas: XYZ-67/68/69 (hereafter referred to as area XYZ) and VU-67 (hereafter referred to as area VU) (Figure 1c) (see 262 Balbo et al., 2012; Santana et al., 2015 for micromorphological description of the 263 264 stratigraphic units). In Table S1 the available C14 dates from Tell Qarassa North are 265 summarised. Area XYZ is dated to 10.7-10.2 ka cal. BP, which is consistent with the 266 EPPNB period in the Levant (Kuijt and Goring-Morris, 2002). In this area, a square-267 shaped stone structure (space A) and an open patio area (space B) were found. The 268 stratigraphy consists of six phases (Figure 1c; see detailed description in Santana et al., 269 2015). Phase I corresponds to an occupation phase characterised by beaten earth floors 270 within the stone structures. In phase II a fire event was documented, which enabled the in 271 situ preservation of a collapsed roof structure in space A (Balbo et al., 2012). After this 272 fire event, a new phase of occupation was identified which included the construction of a 273 new beaten earth floor (phase III). Area XYZ was abandoned after phase III, leading to the 274 accumulation of a first layer of architectural and colluvial debris (phase IV). A second 275 layer of debris dated to 10.7-10.3 ka cal. BP, including large blocks from the sidewalls, was deposited inside the perimeter both in space A and B (unit 21, phase V). During this 276 time (around 10.5-10.2 ka cal. BP), the abandoned structures were re-used as a funerary 277 278 area (Santana et al., 2015). Phase VI in area XYZ corresponds to surface layers slightly 279 affected by agricultural activities.

In the VU area, two main occupation phases were attested. A lower phase dated to 10.5-10.2 ka cal. BP, which was characterised by a thin layer of wood charcoal remains, similar to that attested in phase IV of the XYZ area; and an upper phase where a stone-made wall was found associated to human remains. The upper phase was dated to 10.4-9.9 ka cal. BP
and it is, probably, contemporary to the funerary phase V in area XYZ (see Santana et al.,
2015).

286

# 287 4.1. Pollen analysis

Thirty-four pollen samples were taken from the south-facing profile of square E2 in 288 289 area XYZ (space A) and twenty-one from the south-facing profile of the excavation area VU. The profiles were sampled from bottom to top at 10 cm intervals, avoiding the 290 291 mixture of macroscopic visible layers or structures (Figure 1c). The sedimentary 292 accumulation is interpreted as a sequence of aggradational soils (or surfaces) with very low edaphization imprint. The origin of the sediment is interpreted as aeolian and also 293 294 derived from the reworking of nearby building materials (see detailed descriptions in Santana et al., 2015). Samples from the top of each profile correspond to levels affected by 295 296 current agricultural activities (samples 1 to 6 from phase VI in area XYZ; samples 1 to 4 from VU, Figure 1c) and they were not included in the analyses. An average of 10 g of 297 298 sediment was chemically treated to remove the mineral fractions. The method followed for 299 pollen and non-pollen palynomorphs (NPPs) extraction is that described by Burjachs et al. 300 (2003), where palynomorphs were concentrated using Thoulet liquor (Goeury and de 301 Beaulieu, 1979). The final residue was suspended in glycerine and counted until a pollen 302 sum of 250 grains was reached, excluding NPPs and anthropogenic taxa such Cichorioideae and Cardueae (Bottema, 1975; López-Sáez et al., 2003). Slides were 303 304 examined with a light microscope using a magnification of  $400 \times$  or  $1000 \times$ . Pollen types were identified with pollen keys (Moore et al., 1991), pollen atlases (Reille, 1999), and the 305 306 reference collection of the Archaeobotany Laboratory (CSIC, Madrid, Spain). Cerealia type was defined as Poaceae exceeding 45 µm with a minimum annulus diameter of 8–10 307 308 μm (Beug, 2004; López-Sáez and López-Merino, 2005). The majority of NPPs present on 309 the pollen slides were identified and their nomenclature conforms to van Geel (2001). 310 Pollen diagrams were drawn using TGView (Grimm, 2004). To establish the zonation of the pollen sequences, we tested several divisive and agglomerative methods with the 311 program IBM SPSS Statistics 21. Based on the ecological meaning of the obtained zones, 312 five and two local pollen assemblage zones (LPAZs) were constructed respectively for 313 area XYZ and VU on the basis of agglomerative constrained cluster analysis of 314 incremental sum of squares (Coniss) with square root transformed percentage data 315

316 (Grimm, 1987). The number of statistically significant zones was determined using the
317 broken-stick model (Bennett, 1996).

318

#### 319 *4.2. Wood charcoal analysis*

320 The wood charcoal remains analysed in this study were collected from 64 sediment samples processed with machine-assisted flotation (59 from spaces A and B in area XYZ, 321 322 and five from area VU) (see Arranz-Otaegui, 2016 and Arranz-Otaegui et al., 2016a for details about the sampling and sample processing). The remains corresponded to dispersed 323 324 wood charcoal fragments found in contexts such as infill of structures, open areas, 325 processing areas, pits, refuse and burial contexts. Wood charcoal was identified using descriptions from several atlases (Fahn et al., 1986; Neumann et al., 2001; Schweingruber, 326 327 1990; Vernet, 2001) and the modern wood reference collections housed at the Palaeobotany Laboratory Lydia Zapata (University of the Basque Country, UPV-EHU, 328 Vitoria-Gasteiz), Institute of Archaeology (University College London) and Department of 329 Archaeology, Classics and Egyptology (University of Liverpool). Identifications were 330 331 carried out with the aid of an incident light microscope (Olympus BX50) with different 332 magnifications ( $10 \times$  to  $50 \times$ ). The majority of the wood fragments analysed at Tell Qarassa 333 North was sized between 2-4 mm. In accordance with Chabal (1989, 1991), rare taxa were 334 always smaller than 4 mm, whilst the most common taxa were found both within 2-4 mm 335 and >4 mm size ranges. Saturation curves were used to establish the minimum number of charcoal fragments to be analysed per sample. These curves are exponential, the higher the 336 337 number of species represented in a given sample, the higher the number of charcoal fragments that need to be analysed to grant their statistical representativeness. At Tell 338 339 Qarassa North, saturation curves were used in all samples containing more than 100 wood 340 charcoal fragments and indicated that the identification of 100 wood charcoal fragments 341 was sufficient to ensure taxa representation.

342

# 343 *4.3. Stable carbon isotope analysis*

344 Stable carbon isotope analysis was carried out in wood charcoal remains of *Pistacia* sp. 345 (pistachio) and *Amygdalus* sp. (almond) to characterize the water availability conditions of 346 this site (Araus et al., 2014; Fiorentino et al., 2015). The assemblage includes dispersed 347 wood charcoal remains from different contexts processed with flotation (as described 348 above), as well as charcoal remains from a primary deposit, a burnt roof structure, 349 recovered *in situ* (Balbo et al., 2012). The growth-ring curvature of the wood charcoal fragments was evaluated following Marguerie and Hunot (2007). This method provides information to characterise what part of the tree was used (e.g. trunks or branches) and assess whether biases exist in the isotopic content of biologically old (i.e. trunk) or young (i.e. branch) specimens.

354 Carbonate crusts in charcoals were removed by soaking each charcoal sample separately in 6M HCl for 24 h at room temperature and then rinsing the grain repeatedly 355 356 with distilled water (DeNiro and Hastorf, 1985; Ferrio et al., 2004). All samples were oven-dried at 60°C for 24 h before milling to a fine powder for isotope analyses. The stable 357 isotope composition of carbon ( $\delta^{13}$ C, referred to the VPDB standard) was determined by 358 elemental analysis and isotope ratio mass spectrometry (EA/IRMS) at the Isotope Services 359 of the University of Barcelona (Barcelona, Spain). The overall analytical precision was 360 about 0.1%. Carbon isotope discrimination ( $\Delta^{13}$ C) of archaeobotanical samples was 361 calculated from grain  $\delta^{13}$ C and from the  $\delta^{13}$ C of atmospheric CO<sub>2</sub>, as follows: 362

363

364 
$$\Delta^{13}C(\%) = (\delta^{13}C_{air} - \delta^{13}C_{plant}) / [1 + (\delta^{13}C_{plant} / 1000)]$$

365

where  $\delta^{13}C_{air}$  and  $\delta^{13}C_{plant}$  denote air and plant  $\delta^{13}C$ , respectively (Farquhar et al., 1989). 366 The  $\delta^{13}C_{air}$  was inferred by interpolating a range of data from Antarctic ice-core records 367 together with modern data from two Antarctic stations (Halley Bay and Palmer Station) of 368 CU-INSTAAR/NOAA-CMDL 369 the network for atmospheric  $CO_2$ 370 (ftp://ftp.cmdl.noaa.gov/ccg/co2c13/flask/readme.html), as described elsewhere (Ferrio et al., 2005). The whole  $\delta^{13}C_{air}$  dataset thus obtained covered the period from 16,100 BCE to 371 2003 CE (data available at http://web.udl.es/usuaris/x3845331/AIRCO2\_LOESS.xls). The 372 provenance, dating as well as the  $\delta^{13}$ C and  $\Delta^{13}$ C of each sample used in this study and the 373 corresponding  $\delta^{13}C_{air}$  are detailed in the Supplemental Information Table S2. 374

375

# 376 *4.4. Phytolith analysis*

Seven samples from area XYZ (square E2, south-facing profile) and eleven from area
VU (south profile) were selected for phytolith analysis. Samples were obtained from
different contexts described in the field as filling deposits, open spaces and funerary areas.
The methods used are similar to those developed by Katz et al. (2010). A weighed aliquot
of between 30–40 mg of dried sediment was treated with 50 µl of a volume solution of 6N
HCl. The mineral components of the samples were then separated according to their

383 densities in order to concentrate the phytoliths using 450 µl 2.4 g/ml sodium polytungstate 384 solution  $[Na_6(H_2W_{12}O_{40})]$ . Microscope slides were mounted with 50 µl of material. A minimum of 200 phytoliths with recognizable morphologies was examined at  $200 \times$  and 385 400× using an Olympus BX41 optical microscope at the Department of Prehistory, 386 387 Ancient History and Archaeology from the University of Barcelona. The estimated phytolith numbers per gram of sediment are related to the initial sample weight and allow 388 quantitative comparisons between the samples and excavation areas. Phytoliths that were 389 unidentifiable because of dissolution are listed as weathered morphotypes. Multicellular 390 391 structures (multi-celled or interconnected phytoliths) were also recorded. These latter data 392 may provide information regarding the extent of silification of plant cells, as well as of preservation conditions (Albert and Weiner, 2001; Albert et al., 2008, 2011; Portillo et al., 393 394 2014, 2016). Morphological identification was based on modern plant reference collections from the Mediterranean region (Albert and Weiner, 2001; Albert et al., 2008, 395 2011; Portillo et al., 2014; Tsartsidou et al., 2007) and standard literature (Brown, 1984; 396 Mulholland and Rapp, 1992; Piperno, 1988, 2006; Rosen, 1992; Twiss, 1992; Twiss et al., 397 398 1969). The terms used follow the International Code for Phytolith Nomenclature (Madella 399 et al., 2005).

400

# 401 **5. Results**

# 402 *5.1. Pollen analysis*

An overall good state of preservation of pollen grains and NPPs was found at Tell Qarassa North. A total of 38 pollen and non-pollen palynomorph types were identified. Total pollen and NPP percentages from area XYZ and VU are given in Figures 2 and 3. The percentage pollen diagrams can be divided into five LPAZ zones in area XYZ and two in area VU, which correspond to phases I-V in area XYZ (LPAZs XYZ-I to XYZ-V) and the lower and upper phases in area VU (LPAZs VU-Lower and VU-Upper).

409 In area XYZ the oldest phases I to IV show overall high values for Quercus calliprinos (7-15%) and Q. ithaburensis (15-25%), along with anthropogenic herbs such as Cardueae 410 (5-10%), Cichorioideae (10-20%) and Poaceae (8-13%) (Figure 2). Anthropozoogenous 411 taxa such as Plantago lanceolata (2-6%), Rumex acetosa (~2%), R. acetosella (~2%) and 412 413 Chenopodiaceae (3-7%) are mainly attested in phase III, associated with maximum values of coprophilous fungi (Sordariaceae 4-6%; Chaetomium 4%). Increasing proportions of 414 415 Cerealia are attested from phase I (around 2.2-5.4%) to phase III (around 3.7-6.5%). Most herbs show continuous presence during phases I to IV, but during destruction phases II and 416

417 IV, anthropogenic and zoogenous taxa (Cardueae, Cichorioideae, Chenopodiaceae, Rumex acetosa) sharply decrease, and Cerealia, Plantago lanceolata and Rumex acetosella 418 419 disappear. In addition, the highest concentration of *Glomus* is recorded during these two 420 destruction phases, whilst Sordariaceae disappear. The only difference between the two 421 destruction phases (II and IV) is the high percentages of *Chaetomium* (6-12%) in the latter. Apart from these, phases I-IV are overall characterized by noticeable percentages of 422 423 Juniperus (1-3%), Pistacia (4-7%), Periploca (2-4%), Phillyrea (1-2%), Prunus (2-4%), Olea (1-2%), Rhamnus (2-4%), Sarcopoterium (4-6%) and Zizyphus (3-5%) among the 424 425 shrubs (note that Pistacia and Amygdalus are commonly under-represented in 426 palynological analyses, e.g. Rossignol-Strick, 1993; Roberts, 2002). Wet meadow steppe 427 taxa (Cyperaceae) show very low values (<2%), whilst Artemisia shows its highest percentages during phase IV (6-10%). Values for the rest of taxa, such as Acer (1-2%) and 428 429 *Pinus nigra* (3-5%) remain stable during phases I-IV, whilst *Betula*, *Cedrus*, *Corylus*, *Tamarix, Fraxinus, Populus* and *Salix* types are rare (<2%) and sporadic. 430

- 431
- 432 **Figure 2**. Pollen and NPP diagram from Tell Qarassa North XYZ.
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434 435

During phase V (LPAZ XYZ-5), which corresponds to the abandonment and later reuse of the area for funerary purposes, important changes occur in terms of vegetation
composition (Figure 2). On the one hand, taxa such as *Olea*, *Pistacia* (2-4%), *Quercus calliprinos* (2-4%), *Q. ithaburensis* (6-11%), *Rhamnus* and *Zizyphus* steadily decline and *Periploca* and *Sarcopoterium* disappear. On the other hand, *Betula* (maximum 4%), *Cedrus* (7%), *Fraxinus* (4%), *Populus* (5%), *Salix* (10%) and *Tamarix* (10%) notably

442 increase, as well as Juglans, which is recorded for the first time. Anthropogenic 443 (Cardueae, Cichorioideae) and anthropozoogenic (Chenopodiaceae, Plantago lanceolata, 444 Rumex acetosa, R. acetosella) herbs increase slightly, although Cerealia are absent. 445 Sordariaceae are documented again (4-6%), whereas Chaetomium and Glomus maintain a 446 continuous presence. Also, wet meadow steppe taxa (Cyperaceae 13-15%; Ranunculaceae 2-3%) show highest values during this time, whilst Artemisia drops sharply (<2%). 447

448

Figure 3. Pollen and NPP diagram from Tell Qarassa North VU. 449

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452

453 In area VU (Figure 3), results for the lower phase (LPAZ VU-Lower) indicate relatively 454 high percentages of arboreal pollen mainly comprising Quercus ithaburensis (12-16%), Q. 455 *calliprinos* (5-10%) and *Pistacia* (10-14%), and to lesser extent *Acer*, *Betula*, *Salix* (<4%) and Pinus nigra (3-6%). Other trees such as Tamarix, Populus and Fraxinus as well as 456 457 *Cedrus* are present, but show low percentages (< 2%). Shrubs are abundant, with *Prunus* (~3%), Olea (~2%), Periploca (~2%), Phillyrea (1-2%), Rhamnus (2-3%), Sarcopoterium 458 459 (3-5%) and Zizyphus (3-4%) being the most important taxa. Poaceae (5-12%) are the main 460 herbaceous component. Anthropogenic taxa (Cardueae, Cichorioideae), and anthropozoogenic nitrophilous herbs (Rumex acetosella) are also present although with 461 low percentages, similar to those attested during destruction phases II and IV in area XYZ. 462 463 Hygrophytic taxa (Cyperaceae, Ranunculaceae) are represented by low percentages ( $\sim 2\%$ ), while dry steppe taxa such as Artemisia show high values (6-11%), very similar to the 464 evidence attested in phase IV in area XYZ. However, the lower phase of VU show high 465

values of Cerealia (3.3-6.6%), which are similar to those identified during occupationphase III in area XYZ.

During the upper phase of area VU (Figure 3, LPAZ VU-Upper), the results indicate a 468 synchronous decrease of *Pistacia* (4-8%), *Quercus calliprinos* (3-5%) and *Q. ithaburensis* 469 470 (9-11%), comparable to the decrease observed during phase V in area XYZ. Acer, Pinus nigra and Juniperus maintain similar percentages as those attested during the previous 471 472 period. Betula, Cedrus (4-6%), Fraxinus, Populus, Salix (8-11%) and Tamarix (4-7%) increase significantly, and Juglans (1-2%) appears for the first time. Most of the shrubs 473 474 (Prunus, Olea, Phillyrea) maintain a continuous and significant presence throughout the 475 zone, although other shrub taxa percentages (Rhamnus, Zizyphus) display a decreasing 476 trend, and Sarcopoterium and Periploca disappear. In comparison to the previous phase, 477 anthropogenic and anthropozoogenic taxa such as Cardueae (8-12%), Cichorioideae (9-21%), Rumex acetosa, R. acetosella and Plantago lanceolata (~2%) show an increasing 478 trend, as well as Chenopodiaceae (8-11%), while Cerealia disappear. This is also observed 479 in phase V from area XYZ. Artemisia decreases (<1%) whereas Poaceae (13-19%), 480 Ranunculaceae and Cyperaceae (9-13%) significantly increase their values. NPPs 481 482 indicative of erosion and fire events, as well as pastoral activities (*Chaetomium*, *Glomus*) 483 are at their maximum values in this pollen sequence (23 and 17%, respectively), following synchronous trends. 484

485

486 *5.2. Wood charcoal analysis* 

487 A total of 5274 wood charcoal fragments were analysed and 14 taxa were identified in areas XYZ and VU (see the main taxa found in Figure 4). It must be noted that there were 488 489 no significant differences in terms of species representation by phase (i.e. XYZ-I-V) and 490 by type of context (i.e. infill of structure, open areas etc.). Thus, in Table 1 a summary of 491 the ubiquity and absolute counts for area XYZ and VU is given. The results show that *Pistacia* and *Amygdalus* were the most common taxa in all analysed samples, both in terms 492 493 of ubiquity (between 96.9-98.4% of samples) and absolute counts (between c. 30-50%) 494 (Note that these two taxa might be over-represented in the wood charcoal assemblage, Arranz-Otaegui, 2016). In general, the percentages of Anacardiaceae (including *Pistacia*) 495 slightly decreased from 58.7% in area XYZ to 54.4% in area VU, whereas Rosaceae 496 maintained similar proportions (from 34.2 to 35.5%). The rest of taxa were rare both in 497 498 terms of ubiquity (<35% of samples) and absolute counts (percentage counts <1%). 499 Salicaceae (comprising cf. Salix, Salix, and cf. Populus) was only present in area XYZ

(phases I-IV), along with *Tamarix*, *Cedrus libani* and *Fraxinus*, which were also present but in slightly lower proportions (percentage counts <1%). *Quercus* was only identified in area VU (upper phase) and comprised 1.8% of the assemblage. At least one fragment corresponded to evergreen-type *Quercus* (Fig. 4F), although the presence of deciduous *Quercus* cannot be excluded. Other taxa were rare and only found in specific contexts of the excavation area XYZ, such as *Acer* in a pit sample, Chenopodiaceae in the infill of structure and cf. *Rhamnus* associated to a burial.

507

# 508 5.3. Isotope analysis on wood charcoal

Carbon isotope discrimination ( $\Delta^{13}$ C) values for a total of 74 *Pistacia* and 28 509 Amygdalus wood charcoal samples were analysed (Table S2). Curvature was positively 510 511 assessed in 57 wood charcoal fragments corresponding to scattered remains and 29 samples from the rood structure (Table S2). The results showed the predominance of low 512 curvature fragments (80.7% and 65.5% respectively), followed by medium curvature 513 (12.3% and 10.3% respectively) and strong curvature (7% and 10.3% respectively). There 514 515 were no significant differences in terms of  $\triangle 13C$  between biologically older (e.g. weak 516 curvature) and younger (moderate or strong curvature) specimens from the same phase 517 (Table S3). In fact, in some cases wood charcoal fragments with strong curvature tended to 518 exhibit lower (phase IV) or higher (phase V) values than the fragments with weak 519 curvature. Considering this we cannot conclude that in our study the age of the wood sampled may bias the  $\Delta 13C$  of the samples analysed. Mean values were plotted for the six 520 521 phases studied in the XYZ area and the upper and lower phases of the VU area (Fig. 5). In the case of Amygdalus, values were near 19‰ through all the period studied, whereas for 522 523 Pistacia values were in general slightly lower (but above 18‰). Both species tended to 524 show lower values in phase IV compared with the other five phases. The mean  $\Delta 13C$ 525 values of the samples of the two species recovered from the roof and corresponding to phase II in XYZ area were clearly lower (nearly 18‰ for *Pistacia* and slightly above 17‰ 526 for *Amygdalus*). 527

**Table 1.** Results of the taxonomic analyses of the wood charcoal remains from excavation areas XYZ and VU at Tell Qarassa North.

Taxonomic analysis Scattered remains		XYZ-67/68/69 (number of samples: 59)				VU-67 (number of samples: 5)				Total fragments by taxa			
		counts	% frag. counts	presence	ubiquity (%)	counts	% frag. counts	presence	ubiquity (%)	counts	% frag. counts	presence	ubiquity (%)
woodland- steppe	Pistacia sp.	2556	56.3	57	96.6	238	52.8	5	100.0	2794	56.4	62	96.9
	Anacardiaceae	108	2.4	33	55.9	7	1.6	3	60.0	115	2.3	36	56.3
	Amygdalus sp.	1376	30.3	58	<i>98.3</i>	147	32.6	5	100.0	1523	30.8	63	<i>98.4</i>
	Rosaceae	179	3.9	41	69.5	13	2.9	4	80.0	192	3.9	45	70.3
oak-woodland	Acer sp.	4	0.1	1	1.7	0	0.0	0	0.0	4	0.1	1	1.6
	Quercus sp.	0	0.0	0	0.0	8	1.8	2	40.0	8	0.2	2	3.1
coniferous for.	Cedrus libani	37	0.8	14	23.7	0	0.0	0	0.0	37	0.7	14	21.9
wetland and salt marsh	Salicaceae	192	4.2	26	44.1	0	0.0	0	0.0	192	3.9	11	17.2
	Fraxinus sp.	27	0.5	12	20.3	0	0.0	0	0.0	24	0.5	12	18.8
	Tamarix sp.	43	0.9	20	33.9	1	0.2	1	20.0	44	0.9	21	32.8
	Tamaricaceae	13	0.3	8	13.6	0	0.0	0	0.0	13	0.3	8	12.5
steppe	Chenopodiaceae	2	0.0	2	3.4	0	0.0	0	0.0	2	0.0	1	1.6
	cf. Rhamnus	1	0.0	1	1.7	0	0.0	0	0.0	1	0.0	1	1.6
	cf. Fabaceae	1	0.0	1	1.7	0	0.0	0	0.0	1	0.0	1	1.6
Indeterminate		283		49	83.1	37	8.2	4	80.0	320		53	82.8
other (pith, bark)		1		1	1.7	0	0.0	0	0.0	1		1	1.6
Total		4823	100.0	59	100.0	451	100.0	5	100.0	5274	100.0	64	100.0

**Figure 4**. The wood charcoal taxa found at Tell Qarassa North: A and B) transverse and

532 longitudinal tangential sections of Pistacia sp.; C and D) transverse and longitudinal

tangential sections of Amygdalus sp.; E and F) transverse and longitudinal radial section of

534 Salicaceae cf. Salix; G) transverse section of Fraxinus; H) transverse section of Tamarix; I

- and J) transverse and longitudinal tangential sections of Quercus (evergreen-type); K)
- transverse section of Acer; L) transverse section of cf. Fabaceae; M and N) transverse and
- 537 radial sections (showing scalloped tori) of Cedrus libani; O) transverse section of
- 538 Rhamnus; P) transverse section of Chenopodiaceae.





Fig. 4. (continued).

**Figure 5.** Evolution through time of the carbon isotope discrimination ( $\Delta^{13}$ C) of *Amygdalus* and *Pistacia*. Phases I to VI correspond to the XYZ area, whereas the lower and upper phases refer to the VU area. Values plotted are means ± SE. Details about the individual samples analysed can be found in Table S2.

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557

558 *5.4. Phytolith analysis* 

Phytoliths were abundant in all the samples examined (ranging from 1 to 2.6 million 559 560 phytoliths per gram of sediment in XYZ samples and 0.7 to 1.7 in area VU; Table S4). 561 Overall, the low proportions of weathered phytoliths, together with the presence of multicellular or anatomically or connected phytoliths in most of the samples, are indicative 562 of a good state of preservation of the assemblages. The morphological results indicated 563 564 that grasses dominated the phytolith record, with around 80% or more of all the counted morphotypes (Figure 6). In addition to dicotyledonous morphotypes, diagnostic phytoliths 565 566 from the Cyperaceae family (sedges), which are common in wet environments, were noted 567 in both profiles, although to a lesser extent. Grass phytoliths were divided into the different 568 anatomical plant parts in which they were formed (Figure 6). Epidermal cells from grass 569 leaves and stems, including prickles, bulliform cells and stomata, were observed in all the 570 samples in different amounts (between c. 30-65%). The results show that multi-celled concentrations of these plant parts were high in samples related to mud building materials, 571 572 such as sun-dried adobe compounds (up to 42% in sample 29, in phase II, area XYZ; Table 573 S4 and Figure 7a). Additionally, grass phytoliths derived from their floral parts were 574 abundantly noted in most of the samples (~30% or more of all grass morphotypes).

575 Inflorescences were characterized mainly by decorated dendritic and echinate long cells in addition to epidermal papillae cells (Figure 7b). Grasses belonged to the Pooideae 576 577 subfamily which are common in well-watered woodlands and include major cereals. 578 Multi-celled phytoliths from the husks and culms of Pooids, including Triticum sp. and 579 Hordeum sp. were identified in both profiles (Figure 7c).

580

Fig. 6. Left: Relative abundances of phytoliths obtained from XYZ and VU samples; 581 Right: anatomical origin of grass phytoliths. 582

583





586 Figure 7. Photomicrographs of phytoliths identified in XYZ samples (scale 400×): A) multicellular structure of long cells with stomata from grass stems (sample 29, phase II); 587 588 B) epidermal appendage papillae cells (sample 8, phase V); C) multicellular structure of dendritic long cells with short cell rondels from Pooid husk (sample 29, phase II). 589

590



592

## 593 **6. Discussion**

We follow Meadow's approach of system thinking (2008) to characterise past 594 vegetation at Tell Qarassa North and assess its evolution through time. We consider that 595 596 vegetation represents a system, and it is defined as an interconnected set of elements (e.g. trees, herbs) that are coherently organised to achieve a particular purpose (e.g. to 597 reproduce and survive through time), and that are regulated by different inflows and 598 599 outflows. In the following lines we describe the elements that define the vegetation system at Tell Qarassa North (section 6.1.), as well as characterise the environmental conditions at 600 601 the time of cereal domestication (section 6.2.). Following this, we explore the complex 602 patterns of interaction between the local and regional vegetation around Tell Qarassa 603 North and other systems (e.g. climate and human) from 10.7 to 9.9 ka cal. BP (section 604 6.3.).

605

# 606 *6.1. The elements of the vegetation system*

According to pollen, wood charcoal and phytolith evidence, from 10.7 to 9.9 ka cal. BP,
four main plant formations grew in the area around Tell Qarassa North. These comprised *Pistacia* and *Amygdalus* woodland-steppe, wetland vegetation, Mediterranean open oakwoodlands, and high-mountain coniferous forests (Figure 8).

611 Wood charcoal remains from archaeological sites represent the remains of local and 612 easily collected wood resources (Smart and Hoffman, 1988). The anthracological assemblage showed that *Pistacia* and *Amygdalus* were the preferred source of fuel during 613 614 the whole occupation period (10.7-9.9 ka cal. BP) (Table 1). Considering the morphological characteristics of the nutshells found at the site (Arranz-Otaegui et al., 615 616 2016a), the remains probably represent Amygdalus korshinskyi and Pistacia palaestina/atlantica. These species are nowadays leading elements of Irano-Turanian 617 618 woodland-steppe formations, and grow along with an understory of Poaceae, Chenopodiaceae and other steppic plants (Zohary, 1973). In addition to these, Q. 619 620 ithaburensis is also common in Pistacia-Amygdalus woodland and woodland-steppe formations in the Mediterranean and Irano-Turanian borderlands (Zohary, 1973). This 621 622 association was attested in Bronze Age and Roman sites located in the plains and mountainous areas of Jabal al-Arab, less than 10 km from Tell Qarassa North (Willcox, 623 1999). In modern pollen rain studies conducted in the eastern Mediterranean and the 624 625 Middle East values of *Quercus* pollen higher than 20% indicate the local presence of oak 626 forests or maquis, while percentages of the order of 6-8% reflect the regional nature of 627 their origin (e.g. Bottema, 1977; Davies and Fall, 2001; Kaniewski et al., 2011; Fall, 628 2012). At Tell Qarassa North percentages of *Quercus ithaburensis* pollen were up to 25% (Fig. 2), suggesting that this species could have grown in the vicinity. However, the 629 proportions of Pistacia pollen found at the site (between 4 and 7% in area XYZ and 4-630 631 14% in area VU, Fig. 2; Fig. 3) are indicative of Pistacia tree dominance over Quercus, especially in Amygdalus-closed forest vegetation (Rossignol-Strick, 1995). Considering 632 the remarkable percentages of grasses and steppic plants in the pollen records (Fig. 2; 633 Fig. 3) and the non-woody plant macroremains of the site (Arranz-Otaegui et al., 2016a), it 634 635 is likely that the immediate areas around Tell Qarassa North were characterised by vast open areas with broadly spaced *Pistacia* and *Amygdalus* trees alternating with *Quercus* 636 637 ithaburensis, shrubby Rosaceae, Rhamnus and Acer, and extensive patches of grasses and steppe vegetation such as Capparis, Camelina, Stipa, Trigonella astroites growing within 638 639 the scattered trees (Mouterde, 1953; Zohary, 1973). This type of vegetation would have been primarily located to the south of the tell, where rich soils that allow agricultural 640 activities were found (Fig. 8A), as well as to the north of the site, in the Leja area. The 641 limited tolerance to water-saturated soils of Pistacia and Amygdalus (Zohary, 1973) would 642 643 have made them less common at the eastern foot of the tell due to the existence of a lake 644 (Ibañez et al., 2010a). The prevalence of Pistacia and Amygdalus woodland-steppe vegetation is found during the early Holocene in inland areas of southwest Asia (Fig. S1, 645 646 Table S5), from southern-central Syria (Pessin, 2004; Deckers et al., 2009) up to the 647 Euphrates area (Roitel, 1997), the Anatolian Plateau (Willcox, 1991; Asouti, 2003; 648 Emery-Barbier and Thiébault, 2005), southeast Turkey (Neef, 2003) and the Zagros (van Zeist et al., 1984; Riehl et al., 2015); that is, in areas that nowadays correspond to the 649 650 Irano-Turanian phytogeographical region (Zohary, 1973). An open landscape comprising 651 Pistacia forests and steppe vegetation has also been recorded in early Holocene pollen 652 records from Anatolia (Bottema and Woldring, 1984; Roberts et al., 2001), southeast Turkey (van Zeist and Bottema, 1977; Wick et al., 2003; Litt et al., 2014) and Iran (van 653 Zeist and Bottema, 1977; Bottema, 1986; Djamali et al., 2008b) (Fig. S1). 654

Apart from Irano-Turanian elements, the wood charcoal, pollen and phytolith results reveal that riparian vegetation constituted an important component of the local vegetation at Tell Qarassa North (Table 1, Figures 2 and 3, Table S4). These included hygrophilous taxa such as Salicaceae (*Populus, Salix*), *Fraxinus* and *Tamarix*, along with *Ficus* and *Vitex agnus-castus* that were documented within the non-woody plant macroremains (Arranz-Otaegui et al., 2016a), and annual and perennial plants of the Cyperaceae (e.g. 661 Bolboschoenus glaucus, Eleocharis and Carex) and Ranunculaceae families. Despite their overall low absolute counts in the wood charcoal assemblage of Tell Qarassa North (Table 662 1) it is likely they were used as importance source of fuel (Arranz-Otaegui, 2016) and 663 664 building material (Balbo et al., 2012). Wetland vegetation would have been established 665 around the shores of the ancient lake that was located at the foot of Tell Qarassa North (Figure 8B), as well as in the many water springs and the river fed by the volcanic uplands 666 667 of the Jabal al-Arab (Ibañez et al., 2010b; Braemer et al., 2009). Riparian trees were commonly used as firewood and were an important element of the vegetation at 668 669 contemporary sites across southwest Asia (Western, 1971; Lipshschitz and Noy, 1991; 670 Roitel, 1997; Pessin, 2004; Austin, 2007).

671 The pollen records from Tell Qarassa North show the presence in the area of *Quercus* 672 calliprinos along with a wide range of Mediterranean taxa such as Olea, Rhamnus, 673 Periploca, Phillyrea, Sarcopoterium, Ziziphus and Acer (Figures 2 and 3). Q. calliprinos is the most important element of the maquis in the south-eastern part of the Mediterranean 674 675 area (Zohary, 1973), and it is commonly associated with Pistacia palaestina at altitudes 676 below 900 m, as attested nowadays in the Hermon area (Aharnovich et al., 2014). Bobek 677 (1963) notes that Quercus woodland and woodland-steppe formations commonly replace 678 Pistacia-Amygdalus steppe forests in areas where annual precipitation exceed an average 679 of 500 mm. This pattern is observed in the Jabal al-Arab nowadays. Here, the plains (c. 680 700-900 m a.s.l) with average annual precipitation of around 250-350 mm are characterised by degraded woodland-steppe components, whilst Mediterranean forest 681 682 vegetation composed primarily of *Q. calliprinos* are restricted to an attitude between 1000 and 1500 m a.s.l. and precipitation above 500 mm (Willcox, 1999). This would indicate 683 684 that evergreen Quercus woodlands probably existed, at least, in what is known today as the 685 "Mediterranean island" of the Jabal al-Arab (Figure 8C). However, the presence of several 686 Mediterranean species such as Echinaria capitata, Poa bulbosa, Psilurus incurvus, 687 Taeniatherum caput-medusae and Tolpis virgata within the non-woody plant macroremains of the site (Arranz-Otaegui et al., 2016a) and the identification of 688 evergreen-type Quercus in the wood charcoal assemblage (Figure 4F) indicates 689 690 infiltrations of Mediterranean vegetation close to the site. This is possible considering that 691 moister condition than at present prevailed during the EPPNB in the area (see Balbo et al. 692 2012, see section 6.2), which would enable these plants to grow at lower altitudes than 693 those nowadays (e.g. 1000 m). The regional evidence shows that typically Mediterranean 694 vegetation was predominant during the early Holocene in the southern Levant. Pollen 695 records from Hula (van Zeist et al., 2009), Dead Sea (Litt et al., 2012), Birkat Ram crate 696 (Schiebel, 2013) and Ammiq wetland (Hajar et al., 2008) point out the prevalence of deciduous *Quercus* forests in the mountain areas of the Golan and the Beqaa (Figure S1). 697 698 In the coastal areas of modern-day Israel, the wood charcoal evidence around 10.2 ka cal. 699 BP suggests the presence of Mediterranean evergreen Quercus forests (Caracuta et al., 2014) and Pistacia-Q. calliprinos associations (Liphschitz, 1997), similar to the vegetation 700 701 found nowadays in the same area. In the northern part of the Dead Sea, Pistacia forests 702 and halophytic communities (e.g. Tamarix) grew at low elevations (i.e. around 250 m 703 b.s.l., Liphschitz, 2010; Western, 1971), whilst in the east, at altitudes around 700 m a.s.l., 704 extensive deciduous Quercus woodlands along with some evergreen Quercus components were found (Neef, 2004). In the Jordan Valley, Pistacia trees (Asouti et al., 2015), and 705 706 Juniperus woodlands (Neef, 2004; Austin, 2007) predominated along with some 707 components of evergreen Quercus, indicating that arid areas nowadays characterised as 708 treeless Irano-Turanian steppe and dwarf shrub were moister and more forested than at 709 present.

Mountain vegetation is represented at Tell Qarassa North by the presence of Cedrus 710 711 libani, Betula and Pinus nigra type, as noted in the wood charcoal and pollen records 712 (Figures 2 and 3, Table 1). These taxa are likely to correspond to the 'regional' distance 713 transport of pollen grains from the nearby highland areas (Jabal al-Arab mountain range), 714 or even from more distant regions (e.g. Betula), as suggested in the pollen records from Hula (van Zeist et al. 2009). Mixed deciduous and coniferous forests, which grow in the 715 716 oromediterranean bioclimatic zone of the Syrian and Lebanese mountains, include deciduous oaks, Pinus nigra, Juniperus excelsa and J. oxycedrus reaching up to 1900 m 717 718 a.s.l (Zohary, 1973). At higher elevations coniferous forests mainly comprise Pinus nigra, 719 Abies cilicica and Cedrus libani, along with various juniper species (Juniperus excelsa, J. 720 drupacea, J. phoenicea) (Zohary, 1973). Cedrus libani is now found primarily in the 721 mountainous areas of Lebanon, northern Syria and Turkey (Hajar et al., 2010), although it has also been observed in the Mount Hermon and the northern Golan (Neumann et al., 722 723 2007), around 60 km from Tell Qarassa North. Pollen records from Ammiq wetland in 724 Lebanon (Hajar et al., 2008) suggest that coniferous forests with species such as Cedrus 725 could have been found during the early Holocene in the Barouk Mountains (Figure S1). The presence of *Cedrus* wood charcoal at the PPNB site of Tell Aswad, in the Damascus 726 727 Basin, was interpreted as evidence of long-distance transportation of exotic materials 728 (Willcox, 2005). However, Cedrus libani can adapt to a wide range of soil types and

729 moisture contents, including semi-arid regions with precipitation between 300 and 600 mm 730 per year (Semerci, 2005), and altitudes above 900 m a.s.l., often between 1500-1800 m 731 a.s.l. (Liphschitz and Biger, 1992; Hajar et al., 2010). At 25 km to the east of Tell Qarassa North the uplands of the Jabal al-Arab rise to 1800 m a.s.l., and they could have 732 733 constituted a suitable area for the growth of these conifer forests during the early Holocene (Figure 8D). 734

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Figure 8. Reconstruction of the local vegetation around Tell Qarassa North, view towards 736 737 the south of the site (Author: C. Carlson). A) Woodland-steppe components such as 738 *Pistacia* and *Amygdalus* growing close to the site; B) riparian vegetation growing along 739 the shore of the lake and nearby water ponds; C) evergreen oak stands growing in more 740 distant areas; D) coniferous forests growing in the mountain areas of the Jabal al-Arab (around 25 km from the site). 741

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Overall, the evidence from Tell Qarassa North adds to the mosaic of plant 745 746 formations attested in southwest Asia during the early Holocene (Fig. S1). The regional wood charcoal and pollen datasets highlighted east-west and north-south gradients in 747 woodland composition not only in the southern Levant (Asouti et al., 2015), but also 748 across southwest Asia. The evidence shows that coastal areas were dominated by 749

750 Mediterranean deciduous and evergreen Quercus in the lowlands, and conifer forests at higher altitudes, whilst inland areas were more arid and Pistacia and Rosaceae stands 751 predominated in woodland and woodland-steppe formations (Fig. S1, Table S5). The 752 753 absence of particular taxa such as deciduous Quercus south of the Dead Sea (Fig. S1) 754 indicates that moisture conditions were not sufficient for this tree to grow in these regions 755 (Asouti et al., 2015), highlighting north-south gradients in the distribution of certain plant 756 communities. This may also apply to Amygdalus, a cold-tolerant species that was rarely attested in the southern Levant during the early Holocene, but predominated along with 757 758 Pistacia in inland areas starting from southern Syria up to the northern Levant, Anatolia and the Zagros (Fig. S1, Table S5). Early Holocene records show that areas that nowadays 759 760 receive low precipitation (e.g. Jordan Valley) were considerably moister than at present, 761 and allowed the development of more extensive forests. This pattern is also evidenced at 762 Tell Qarassa North by the presence of evergreen and deciduous Quercus. Notwithstanding 763 that early Holocene vegetationwas not stable and changed in relation to centennial-scale climatic fluctuations and anthropogenic impacts (among other factors), the type of plant 764 formations found during this time broadly match the limits of modern-day 765 766 phytogeographical regions in southwest Asia.

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# 768 6.2. The palaeoenviromental conditions at the time of cereal domestication

769 The analyses of the non-woody plant macroremains (Arranz-Otaegui et al., 2016a) and microremains (Figure 2, 3 6, and 7) from Tell Qarassa North indicate that cereal 770 771 cultivation was common practice since the earliest occupation phases of the site (i.e., area XYZ phase I-IV, 10.7-10.5 ka cal. BP). The presence of cereal pollen at Tell Qarassa 772 773 North suggests cultivation took place in the vicinity, probably in the lands located towards 774 the south of the site (Arranz-Otaegui et al., 2016a; López-Sáez and López-Merino, 2005). 775 The fact that around 30% of the cereal crops bear characteristics of domesticated species 776 (i.e. tough-rachis) indicates that since 10.7 ka cal. BP inhabitants cultivated both wild and domesticated (*T*. dicoccoides/dicoccum), (*T*. 777 emmer einkorn 778 boeoticum/urartu/monococcum), and lesser barley (Hordeum to a extent spontaneum/vulgare) (Arranz-Otaegui et al., 2016a). This evidence contrasts with that 779 780 observed at contemporary sites in the southern-central Levant, where barley is the most 781 common species exploited (see summary in Arranz-Otaegui et al., 2016b).

782 It is likely that the environmental conditions around Tell Qarassa North were more 783 humid than in the rest of the sites in the southern Levant and allowed the exploitation of 784 wheat over barley. The minimum rainfall requirements for these cereals present at Tell 785 Qarassa North is approximately 200 mm for Hordeum spontaneum, 250 mm for T. urartu, 300 mm for T. boeoticum and 400 mm for T. dicoccoides (Willcox, 2005; Heun et al., 786 2008). The widespread presence of emmer in the assemblage indicates that the minimum 787 788 annual precipitation around 10.7-9.9 ka cal. BP must have been of around 400 mm. This estimate is confirmed by the habitat requirements of the tree species found at the site. Q. 789 790 *ithaburensis* is largely dependent on the amount of precipitation and it commonly needs annual average rainfall above 400 mm (Bobek, 1963; Zohary, 1973). Pistacia atlantica 791 792 and Amygdalus korschinskii commonly grow in areas with average rainfall 300-400 mm per year (Bobek, 1963). The high  $\Delta^{13}$ C values recorded in the charcoal of *Pistacia* and 793 Amygdalus from Tell Qarassa North indicate that these trees were growing in relatively 794 795 wet conditions, prevalent at other early agricultural sites (Araus et al., 2014). In the case of *Pistacia*, the  $\Delta^{13}$ C values were similar to those recorded at Epipaleolithic and Neolithic 796 797 sites in the northern Syria and southeastern Turkey (Araus et al., 2014), including those recorded in the second half of the Holocene (Deckers, 2016). Yet, the values found at Tell 798 799 Qarassa North were slightly higher than present-day values in the region (Masi et al., 800 2013; Araus et al., 2014), indicating that cereal domestication took place at a time of 801 moister environmental conditions (i.e. >350 mm, Traboulsi, 2013). It is also noteworthy 802 that *Pistacia* and *Amygdalus* charcoals from the roof structure exhibited lower values in 803 contrast to dispersed wood charcoal remains derived from fuel waste (Figure 5). These results cannot be explained by the biological age of the wood charcoal fragments analysed 804 805 (i.e. deriving either from trunks or from branches) (Table S3). Moreover the available literature does not conclusively support the effect of age on the  $\Delta 13C$  of the wood charcoal 806 807 (Tans and Mook, 1980; Leavitt and Long, 1986; Schleser, 1992; Nguyen-Queyrens et al., 808 1998; Fotelli et al., 2009). Instead, it could be that the building materials were gathered in 809 a different location in comparison to fuel resources, probably beyond the agricultural 810 surroundings of the site, in less fertile locations such as those found towards the north, in 811 the Leja area.

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# 813 6.3. The dynamics of past vegetation around 10.5-9.9 ka cal. BP

For around 200-300 years, plant formation around Tell Qarassa North did not suffer major changes indicating that the whole vegetation system worked in dynamic equilibrium. This means that from 10.7 to 10.5 ka cal. BP the inflows and outflows that regulated the amount and the type of trees present in the area were balanced. The sum of 818 all outflows (e.g. natural death of trees, wood gathering and fire-related activities) equalled 819 the sum of all inflows (e.g. natural reproduction of trees, tree management activities), and 820 therefore, allowed the different plant formation growing around Tell Qarassa North (i.e. 821 woodlands-steppe, oak-woodlands, riparian vegetation and mountain vegetation) to 822 maintain relatively unchanged. However, between c. 10.5 and 9.9 ka cal. BP (phase V in area XYZ, and the upper phase in area VU), several changes occur in some of the outflows 823 824 and inflows that regulate the vegetation system, in particular in those related to the climate 825 system and the human system, leading to substantial transformations in the local and 826 regional vegetation.

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#### 828 6.3.1. *Changes in the climate system*

829 The latest occupation phases of Tell Qarassa North dated to between 10.5 and 9.9 k cal. BP (phase V in area XYZ and upper phase in area VU), highlight changes in the 830 proportions of trees that are sensitive to temperature fluctuations. The pollen records show 831 832 a marked decrease in thermophilous taxa such as Pistacia, Periploca, Sarcopoterium and 833 Zizyphus and Quercus calliprinos (Figures 2 and 3). This trend is synchronous with the 834 increase in the pollen of mesophilous trees such as Betula and Cedrus, and the first 835 appearance in the assemblage of typically mesophilous Junglans (Figures 2 and 3). The shifts observed suggest that between 10.5 and 9.9 ka cal. BP, cold environmental 836 837 conditions established around Tell Qarassa North. Regional datasets show that centennial-838 scale rapid climatic changes occurred during the Holocene in the Mediterranean region, 839 and comprised changes in temperature and rainfall conditions (Mayewski et al., 2004). Based on the Glacial GISP2 non sea-salt (nss) potassium [K<sup>+</sup>] concentration record, 840 841 Weninger et al. (2009) suggested that one of the coldest events during the last 50,000 years 842 occurred at around 10.2 ka cal. BP in the eastern Mediterranean. The 10.2 ka cal. BP event 843 was previously identified in other regions of the Northern Hemisphere (Bond et al., 1997; Rasmussen et al., 2007; Cai et al., 2008), however, so far, it has not been identified in 844 Mediterranean pollen records. This rapid climatic change has been associated to a major 845 interruption in the sequence of settlements in the northern Levant and it has been referred 846 to as possible trigger for the abandonment of several Pre-Pottery Neolithic sites (Borrell et 847 848 al., 2015). At Tell Qarassa North, the reduction of thermophilous species opposed to 849 mesophilous species is a possible signal of a climatic change contemporary with the 10.2 850 ka cal. BP event. Most of the mesophilous and thermophilous species that show changes during this time were probably growing at a considerable distance from the site (see 851

852 section 6.1.), and therefore, human factors can be excluded as possible explanations for 853 their diminution/increase. Furthermore, during other cold rapid climatic changes such as 854 the 8.2 ka cal. BP, a decrease in thermophilous species such as *Quercus calliprinos* has 855 been recorded in several pollen records in the Mediterranean area (Rossignol-Strick, 1999; 856 Pross et al., 2009). Besides, most of the mesophilous and thermophilous species that showed changes during this time were probably growing at a considerable distance from 857 858 the site (see Section 6.1.), and therefore, human factors can be excluded as possible explanations. Considering this, it is likely that the establishment of colder environmental 859 860 conditions between 10.5 and 9.9 ka cal. BP acted as an outflow on the flora of the Jabal al-861 Arab region reducing the extension of thermophilous taxa.

862 Besides this, temperature fluctuations could have acted as a reinforcing feedback loop, 863 and enhanced further transformations in the local and regional vegetation. Decrease 864 temperatures commonly result in higher snow accumulations and ice melt water, which 865 condition the growth of alluvial fans in valley bottoms, and the rise in the water table of rivers, lakes and water ponds. In Europe, several studies have identified hydrological 866 changes (e.g. floods) as a consequence of the 8.2 ka cal. BP cooling episode (Alley and 867 868 Agustsfottir, 2005; Hughes et al. 2000; Magny et al., 2003). In the Anatolian Plateau, the 869 expansion of alluvial fans around 9.5 ka cal. BP (Boyer et al. 2006) were referred to as a 870 possible signal of a climatic change contemporary with the cold 9.2 ka cal BP event 871 (Berger et al., 2016). In Cyprus, flood episodes that caused strong upstream erosion (Devillers, 2005), as well as surface erosion and torrential discharges were attested around 872 873 8.5 ka cal. BP and 8.1 ka cal. BP (Berger et al., 2016), which could be linked to 8.2 ka cal. BP event. In the Lake Van, high water tables associated to increased sedimentation and 874 875 mineral content were recorded also around 8.4-8.2 ka cal. BP (Lemcke and Sturm, 1997). 876 Considering that hygrophilous plants represent edaphic communities that depend on 877 ground moisture and water availability (Zohary, 1973), changes in the water table of the 878 nearby water ponds and springs caused by the establishment of colder environmental 879 conditions could have also altered the extent to which this plant formations grew in the vicinity. This hypothesis would explain the synchronous spread of mesophilous species 880 and the development of hygrophilous and meadow steppe attested taxa between 10.5 and 881 882 9.9 ka cal. BP at Tell Qarassa North (Figures 2 and 3).

883 An additional factor that could have contributed to the spread of hygrophilous plants 884 has to do with the other main element that regulates plant growth in the climate system that 885 is rainfall. The isotope record from Tell Qarassa North indicated centurial changes in the 886 isotopic content of the wood charcoal samples studied. In area XYZ, Pistacia and Amygdalus  $\Delta^{13}$ C values decreased from phase I to phase IV, indicating that the second 887 destruction of the site (phase IV) occurred at the time of dry environmental conditions in 888 comparison to earlier occupation phases, and which coincide with maximum values for 889 890 dry-tolerant Artemisia in the pollen samples from phase IV (Figure 2). This period was followed by increased values during the last phases of the site (phase V and VI in XYZ) 891 892 and upper and lower phase in VU), indicating the re-establishment of wet conditions. At Tell Qarassa North, the spread of wetland taxa in phase V of area XYZ and upper phase of 893 894 area VU is coincidental with the disappearance of Artemisia (Figures 2 and 3), a common 895 indicator of dryness in the pollen records (Rossignol-Strick, 1995) and increase in Poaceae 896 (e.g., from 5-12% to 13-19% in area VU, Figures 2 and 3). The increase in Poaceae pollen 897 at the expense of Artemisia is suggestive of reduced summer drought or increase summer 898 precipitation. In previous studies, high percentage of Poaceae pollen in deep-core pollen 899 records from the Arabo-Persian Gulf were interpreted as evidence of reduced extreme summer drought around 8.0 ka cal. BP (el-Moslimany, 1983). The evidence would thus 900 901 indicate that between 10.5 and 9.9 ka cal. BP environmental conditions around Tell 902 Qarassa North not only turned colder, but also moister. This is in accordance with the 903 regional datasets from the Mediterranean area, which indicate that after the 10.2 ka cal. 904 BP, around 10-8.6 ka cal. BP, extremely wet conditions prevailed, referred to as the 905 Levantine Moist Period (LMP). These conditions have been best documented in the Dead 906 Sea (Weninger et al., 2009; Arz et al., 2003b; Migowski et al., 2006), located around 150 907 km to the west of Tell Qarassa North. The stable carbon isotopes from Soreq Cave (Israel) indicate that during this time regional rainfall could have been twice higher than the 908 909 present-day average (Bar-Matthews et al., 2000). Recent stable carbon isotope analyses of 910 archaeological plant remains from Neolithic sites in the Middle Euphrates confirm a peak 911 in humid conditions between 10.0 and 8.0 ka cal. BP (Araus et al., 2014). It is thus possible that increased rainfall conditions in the Jabal al-Arab produced changes in the 912 913 water tables of water ponds and lakes located in the plain, and this could have contributed 914 to the development of wetland vegetation around Tell Qarassa North.

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# 6.3.1. Changes in the human system

917 The pollen records from Tell Qarassa North show a remarkable decrease in arboreal 918 pollen between 10.5 and 9.9 ka cal. BP (Figures 2 and 3). In area XYZ, *Quercus* 919 *ithaburensis, Quercus calliprinos* and *Pistacia* pollen values decreased from 15-25% 920 (phases I-IV) to 6-11% (phase V), from 7-15% (phases I-IV) to 2-4% (phase V) and from 921 4-7% (phases I-IV) to 2-4% (phase V) respectively, and this decrease is also attested in 922 area VU (Figures 2 and 3). Whilst the evidence does not suggest massive deforestation, it 923 does indicate a shift towards an open landscape and overall lower tree cover than in 924 previous periods. The decrease in Mediterranean vegetation comprising thermophilous 925 species such as Q. calliprinos could have been triggered by changes in the climate system 926 (section 6.3.1). However, the evidence shows that changes in the arboreal cover occurred at the time of increased evidence for anthropogenic pressures (Figures 2 and 3). This 927 928 means that plant formation that grew in the immediate vicinity of the site (e.g. Pistacia, Q. 929 ithaburensis) would have been regulated by additional inflows and outflows associated to 930 the anthropogenic system.

931 The pollen records for the latest occupation phases of the site (phase V in area XYZ, and upper phase in area VU) indicate a sudden rise in anthropozoogenic taxa 932 (Chenopodiaceae, Plantago lanceolata, Rumex acetosa, R. acetosella), which refer to 933 plants related to grazed pastures (Behre, 1981); coprophilous fungi (Sordariaceae, 934 935 Chaetomium), which commonly develop on dung (van Geel, 2001). This indicates that 936 between 10.5 and 9.9 ka cal BP, coinciding with the development of agropastoral societies 937 in southwest Asia (Asouti and Fuller, 2012, 2013; Zeder, 2011), herding activities 938 intensified in the area around Tell Qarassa North. The preliminary analyses of the faunal 939 remains from Tell Qarassa North revealed the primary exploitation of goat (Capra format aegagrus) during all the occupations (L. Gourichon in Ibáñez et al., 2010), along with a 940 941 large spectrum of animal taxa comprising other ungulates like the gazelle, the aurochs, the wild boar and the Mesopotamian fallow deer, and the hare and various species of 942 943 carnivores and birds as small game (see Table S6). Sheep bones have not been clearly 944 identified and the goat remains show the same size range (though slightly larger in 945 average) that the goat populations from the late Early and Middle PPNB levels of Tell Aswad where evidence of herding was attested (Helmer and Gourichon 2008, 2016). If the 946 947 domestic status of the goats from Tell Qarassa cannot be asserted from metrical or morphological criteria or kill-off profiles, due to the lack of data, the results provided by 948 the study of NPPs shed new light on this question. The regular occurrence of coprophilous 949 950 fungi (Sordariaceae) throughout the sequence indicates the prevalence of ungulate dung 951 around and within the habitat that cannot be explained solely by incidental deposits from 952 the intestinal contents of wild animals butchered in the surroundings. In this sense, these 953 data strongly suggest that at least part of the goats were herded near Tell Qarassa North, at
954 a time where early domestication of the bezoar goat was demonstrated in Northern 955 Mesopotamia (Peters et al., 2005). It must be considered that compared to sheep, goats are preferentially browsers and can remove tree seedlings, reducing the rates of natural 956 957 woodland regeneration (Janis, 2008; Skarpe and Hester 2008). Several researchers 958 suggested that overgrazing was partially responsible for the reduction in plant cover in regions associated to the emergence of sheep/goat pastoralism, resulting in changes in 959 960 settlement patterns as early as the PPNB (Falconer and Fall, 1995; Grigson, 1995; Köhler-Rollefson, 1988; Köhler-Rollefson and Rollefson, 1990; Simmons, 2000; Tchernov and 961 962 Horwitz, 1990). Despite it is difficult to test, it is possible that increased herding activities 963 between 10.5 and 9.9 ka cal. BP acted as an outflow and reduced the chances for local 964 trees such as *Pistacia* or deciduous *Quercus* to reproduce. This change, coupled with the 965 shift to colder environmental conditions (section 6.3.1), would have hindered the 966 maintenance of the arboreal cover in proportions similar to those attested in previous 967 phases (i.e. I-IV in area XYZ, and lower-phase in area VU).

Additionally, the evidence between 10.5 and 9.9 ka cal. BP shows a marked increase 968 969 carbonicolous fungi such as Chaetomium, a common indicator of anthropogenic fires 970 (López-Sáez et al., 1998; van Geel et al., 2003; López-Sáez and López-Merino 2007); as 971 well as increased *Glomus* values, which have been associated to erosive processes related 972 to the anthropic dynamics in the immediate environment of archaeological sites (López-973 Sáez et al., 2000). The evidence thus indicates increased firing activities in the area. The purpose of theses fires is difficult to asses, but fire management is in general associated 974 975 with hunter-gatherers, pastoralists and cultivators that aim to maintain open savannah-type 976 landscapes with grasslands and trees suitable for agropastoral activities (Roberts, 2002), 977 and Tell Qarassa North the evidence coincided with the time when herding activities 978 intensified and arboreal cover reduced. Regional datasets indicate that grasslands reached 979 maximum values during the early Holocene and dry-season burning was one of the main 980 factors regulating these grass-parkland ecosystems (Turner et al., 2010). Grasses represent competitors for the development of *Quercus* seedlings and they can hamper the expansion 981 982 of oak-woodlands (see recent review by Asouti and Kabukcu, 2014). In the Mediterranean region, low-intensity ground fires are common in the summer dry season, and favour the 983 984 development of wild cereal grasses (Zohary and Hopf, 2000; Grove and Rackham 2001). It is thus likely that increased fire-related and herding activities, as well as additional 985 986 changes in the climate system, all contributed as direct or indirect factors to the decline of 987 the local arboreal cover between 10.5 and 9.9 ka cal. BP.

## 989 **7. Conclusions**

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991 The analyses carried out at Tell Qarassa North show the importance of considering 992 multiple datasets (e.g. plant macro and microremains) to reconstruct past vegetation and 993 environmental conditions in southwest Asia. The multi-proxy analyses at the site have 994 provided high-resolution data to characterise the local and regional vegetation and its evolution at the time when morphologically domesticated cereals appear and developed in 995 996 southern Syria (10.7-9.9 ka cal. BP). The combination of wood charcoal and pollen 997 evidence indicates that Tell Qarassa North was located within the Irano-Turanian and Mediterranean phytogeographical regions. The local vegetation comprised woodland-998 999 steppe components and riparian taxa, whilst Mediterranean oak-woodlands and coniferous 1000 forests could have grown at further distance, in the mountain areas of the Jabal al-Arab located to the east of the site. The results overall indicate that considerably moister 1001 conditions than at present prevailed around Tell Qarassa North and the Jabal al-Arab, 1002 which is consistent with climatic and environmental conditions during the early Holocene 1003 1004 (Robinson et al., 2006; Weninger et al., 2009). Furthermore, the evidence shows that the 1005 site was located also in amore humid area in comparison to coeval sites in the southern Levant, and could explain why the inhabitants of site exploited predominantly wheat 1006 1007 species opposed to barley. Cereal domestication in southern Syria occurred at a time when vegetation, climate and human groups interacted in dynamic equilibrium and the 1008 1009 environment was characterised by mild winters (probably frost-free) and hot summers, and 1010 an average rainfall of around 400 mm per year.

1011 Slightly later, between 10.5 and 9.9 ka cal. BP, the inflows and outflows that regulated 1012 vegetation and that were dependant upon climate and human activities were altered, and 1013 resulted in substantial transformations in the local and regional vegetation. Our results 1014 provide evidence for the spread of mesophilous and hygrophilous taxa during this time, and suggest the establishment of colder and wetter environmental conditions than today. 1015 These fluctuations occurred during a broad time frame (from 10.5 to 9.9 ka cal. BP) and 1016 while they cannot be directly correlated with specific RCCs (e.g. the 10.2 ka cal. BP), it is 1017 1018 likely that they were triggered by shifts in the inflows and outflows associated to the 1019 climate system (e.g. rainfall, temperature). Considering that climatic anomalies vary in 1020 time, space, intensity and type of signal, further investigations are needed to compare the 1021 shifts observed in this study with records from other regions across southwest Asia. Apart from this, pollen records from Tell Qarassa North showed increased fire-related and herding activities from 10.5 to 9.9 ka cal. BP, which along with changes in the climatic conditions, could have enhanced the spread of grasses and the shift to an open landscape with less arboreal cover. At this regard, more studies are necessary not only to identify the presence of anthropogenic impacts in the wood charcoal and pollen records, but also to fully evaluate how human activities altered local plant formations beyond linear models that link human activities to the decrease of the arboreal cover and deforestation.

Overall, in this work we show that changes in the past vegetation were complex in that they involved elements of different systems acting synergistically, and causing plantspecific responses. This means that single factor explanations (i.e., climatic or anthropogenic) of plant change during the Holocene will fail to recognize the diversity and complexity of the interactions that commonly regulate plant ecosystems.

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- 1053

## 1054 Supplementary data

**Table S1.** Available radiocarbon dates for Tell Qarassa North, area XYZ and VU. Radiocarbon determinations were performed in charcoal samples at Beta Analytic Inc. (Miami, Florida, USA) and Centro Nacional de Aceleradores (Sevilla, Spain). Radiocarbon ages were calibrated with OxCalv4.2.2 (Bronk-Ramsey, 2009) using the IntCal09 calibration curve (Reimer et al., 2009).

Area	Phase/ Group	Space	Unit	Phase Interpretation	Reference	14C BP	cal BP	cal BC	Dated material
	Ι	В	<b>52C</b>	1° Occupation	CNA - 1355	9185±40	10487-10244	8538-8295	T. dicoccoides/dicoccum
		٨	57		CNA - 1065	9300±45	10651-10298	8702-8349	<i>Pistacia</i> sp. (Branch BB48)
	II	A	51	1° Destruction	Beta - 290929	9340±50	10700-10407	8751-8458	T. boeoticum/monococcum
		А	74		-	-	-	-	-
XYZ- 67/68/69		В	52B		-	-	-	-	-
		А	24b; <b>25</b>	2º Oceanotien	CNA - 1353	9252±38	10555-10279	8606-8330	T. boeoticum/monococcum
01100105		В	52	2 Occupation	CNA - 1354	9292±48	10648-10291	8699-8342	T. boeoticum/monococcum
	137	А	24;36;37	2º Destruction	-	-	-	-	-
	11	В	14	2 <sup>*</sup> Destruction	-	-	-	-	-
	•	А	21	Abandonment	Beta - 272103	9320±50	10683-10301	8734-8352	Large-seeded Poaceae
	v	А	<b>34</b> ;18;5;6	Cemetery	Beta - 262213	9100±60	10480-10178	8531-8229	T. dicoccoides/dicoccum
	VI	А	<b>15</b> ;3;4	Surface layers	Beta - 277177	9300±50	10653-10296	8704-8347	Triticum spp.
VU-67		Lower	<b>14.15</b> .10	Lower phase	CNA-3129	9192±40	10490-10246	8541-8297	Leguminosae seed
		Lower <b>14;15</b> ;10		Lower phase	Beta - 402487	9100±30	10493-10200	8344-8251	Wood charcoal
		Upper	<b>4;</b> 3	Upper phase	Beta - 274098	9030±60	10368-9919	8419-7970	Leguminosae seed

**Table S2.** Carbon isotope discrimination ( $\Delta^{13}$ C) values of the *Pistacia* and *Amygdalus* wood charcoal remains from Tell Qarassa North. Sample reference and location as well as dating, growth-ring curvature and carbon isotope composition ( $\delta^{13}$ C<sub>sample</sub>) values are listed for each sample. Spaces A and B belong to the XYZ area, whereas the upper and lower phases refer to the VU area.

Sample Nº	Sample ID	Layer	Growth-ring Curvature	<i>Pistacia</i> sp.	<i>Amygdalus</i> sp.	Reference	Data BP	%C	δ <sup>13</sup> Csample (‰)	δ <sup>13</sup> Cair (‰)	Δ <sup>13</sup> C (‰)
1	Z67 Y67	Space A, phase IV	weak	Х				64.71	-24.67	-6.73	18.40
2	Z67D/E 5	Space A, phase IV	weak	Х				65.19	-24.88	-6.73	18.61
8	Y68	Space A, phase IV	moderate		Х			62.98	-25.08	-6.73	18.82
12	Y67	Space A, phase IV	strong	Х				64.81	-23.37	-6.73	17.04
14	Y67 C2	Space A, phase IV	-	Х				65.57	-22.79	-6.73	16.44
15	Y67 D2	Space A, phase IV	moderate		Х			64.17	-24.88	-6.73	18.62
17	Y68	Space A, phase IV	weak	Х				65.53	-25.11	-6.73	18.85
51	Y67 C/D1	Space A, phase IV	strong	Х				67.63	-25.07	-6.73	18.82
24	Y67 E2	Space A, phase IV	weak	Х				62.06	-24.64	-6.73	18.37
3	Y67	Space A, phase VI	moderate		Х	Beta - 277177	$9300\pm50$	61.96	-25.59	-6.73	19.35
11	Y67	Space A, phase VI	weak		Х	Beta - 277177	$9300\pm50$	65.46	-24.86	-6.73	18.58
20	Y67 E2	Space A, phase VI	-		Х	Beta - 277177	$9300\pm50$	63.43	-25.45	-6.73	19.21
5	Y68	Space A, phase VI	-	Х		Beta - 277177	$9300\pm50$	63.95	-24.49	-6.73	18.20
6	Y67	Space A, phase VI	weak		Х	Beta - 277177	$9300\pm50$	63.33	-24.15	-6.73	17.84
10	Y67	Space A, phase VI	moderate		Х	Beta - 277177	$9300\pm50$	62.98	-25.96	-6.73	19.74
23	Y67 E2	Space A, phase V (cemetery)	strong		Х	Beta - 262213	$9100\pm60$	64.20	-24.97	-6.72	18.71
13	Y67 C3	Space A, phase V (cemetery)	strong		Х	Beta - 262213	$9100\pm60$	65.83	-25.66	-6.72	19.43

Sample N°	Sample ID	Layer	Growth-ring Curvature	Pistacia sp.	<i>Amygdalus</i> sp.	Reference	Data BP	%C	δ <sup>13</sup> Csample (‰)	δ <sup>13</sup> Cair (‰)	Δ <sup>13</sup> C (‰)
18	Y67 E2	Space A, phase V (abandonment)	weak		Х	Beta - 272103	$9320\pm50$	62.56	-24.87	-6.74	18.60
9	Y67 D3	Space A, phase V (abandonment)	weak		Х	Beta - 272103	$9320\pm50$	95.05	-24.58	-6.74	18.29
4	V67	Upper phase	weak	Х		Beta - 274098	$9030\pm60$	64.74	-25.29	-6.70	19.07
7	V67	weaker phase	weak	Х		Beta - 402487	$9100 \pm 30$	63.28	-25.30	-6.70	19.09
16	V67	Upper phase	moderate	Х		Beta - 274098	$9030\pm60$	64.95	-25.53	-6.70	19.32
22	V67	Upper phase	weak	Х		Beta - 274098	$9030\pm60$	65.22	-25.69	-6.70	19.49
25	V67	weaker phase	weak		Х	CNA-3129	$9192\pm40$	62.70	-25.00	-6.70	18.76
50	Y67 E3	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	55.78	-22.57	-6.73	16.21
52	Y67 E4	Space A, phase III	weak		Х	CNA1353	$9252\pm38$	64.84	-23.61	-6.73	17.29
55	Y67 E1	Space A, phase III	weak		Х	CNA1353	$9252\pm38$	64.34	-25.78	-6.73	19.56
56	Y68 A4	Space A, phase III	-		Х	CNA1353	$9252\pm38$	61.79	-25.31	-6.73	19.07
57	Y68 A1	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	68.08	-24.44	-6.73	18.16
58	Y67 D1	Space A, phase III	weak		Х	CNA1353	$9252\pm38$	63.20	-25.16	-6.73	18.91
59	Y67 D2	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	65.53	-25.18	-6.73	18.93
60	Y68 A2	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	64.87	-24.61	-6.73	18.33
61	Y68 A2	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	66.20	-24.86	-6.73	18.60
62	Y67 E3	Space A, phase III	weak		Х	CNA1353	$9252\pm38$	56.57	-23.86	-6.73	17.56
65	Y67 E3	Space A, phase II	-		Х	Beta - 290929	$9340\pm50$	64.44	-25.18	-6.74	18.91
66	Y67 C3	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	65.49	-25.34	-6.73	19.10
79	Y67 D3	Space A, phase III	weak		Х	CNA1353	$9252\pm38$	62.62	-25.28	-6.73	19.04
81	Y67 D2	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	61.88	-26.50	-6.73	20.31
82	Y67 D3	Space A, phase III	-	Х		CNA1353	$9252\pm38$	58.14	-22.21	-6.73	15.83

Sample N°	Sample ID	Layer	Growth-ring Curvature	Pistacia sp.	Amygdalus sp.	Reference	Data BP	%C	δ <sup>13</sup> Csample (‰)	δ <sup>13</sup> Cair (‰)	Δ <sup>13</sup> C (‰)
84	Y67 C/D1	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	64.62	-24.16	-6.73	17.87
86	Y67 C1	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	58.06	-22.73	-6.73	16.38
87	Y67 D2	Space A, phase III	weak	Х		CNA1353	$9252\pm38$	52.43	-24.18	-6.73	17.89
89	Y67 E3	Space A, phase III	-	Х		CNA1353	$9252\pm38$	57.85	-23.37	-6.73	17.04
90	Y67 E1	Space A, phase III	-	Х		CNA1353	$9252\pm38$	57.16	-25.12	-6.73	18.87
91	Y67 E3	Space A, phase II, roof	-	Х		Beta - 290929	$9340\pm50$	61.46	-23.40	-6.74	17.06
94	Y67 E2	Space A, phase II, roof	weak	Х		Beta - 290929	$9340\pm50$	53.32	-24.37	-6.74	18.07
95	Y67 E2	Space A, phase II, roof	weak	Х		Beta - 290929	$9340\pm50$	59.98	-24.38	-6.74	18.08
96	Y67 D2	Space A, phase II, roof (post)	weak	Х		Beta - 290929	$9340\pm50$	55.45	-25.89	-6.74	19.66
75	Y67 E/D1	Space A, phase III (pit)	weak	Х		CNA1353	$9252\pm38$	64.66	-24.80	-6.73	18.54
76	Y67 E/D1	Space A, phase III (pit)	weak	Х		CNA1353	$9252\pm38$	60.52	-25.01	-6.73	18.76
54	X68 B1	Space B, phase III	weak	Х		CNA1354	$9292 \hspace{.1in} \pm \hspace{.1in} 48$	63.99	-25.85	-6.73	19.63
63	Y68 D5	Space B, phase III	weak	Х		CNA1354	$9292 \hspace{0.1in} \pm \hspace{0.1in} 48$	61.72	-26.85	-6.73	20.67
64	Y68 C5	Space B, phase III	moderate	Х		CNA1354	$9292 \hspace{0.1in} \pm \hspace{0.1in} 48$	64.92	-24.95	-6.73	18.68
77	X69 A1	Space B, phase III	weak	Х		CNA1354	$9292 \ \pm 48$	62.76	-25.46	-6.73	19.22
92	Y68 C4	Space B, phase III	weak	Х		CNA1354	$9292 \ \pm 48$	64.14	-25.75	-6.73	19.52
93	Y68 E4	Space B, phase III	weak		Х	CNA1354	$9292 \hspace{.1in} \pm \hspace{.1in} 48$	62.70	-26.52	-6.73	20.33
68	Y68 B5	Space B, phase III	weak	Х		CNA1354	$9292 \ \pm 48$	61.49	-25.66	-6.73	19.42

Sample Nº	Sample ID	Layer	Growth-ring Curvature	Pistacia sp.	<i>Amygdalu</i> s sp.	Reference	Data BP	%C	δ <sup>13</sup> Csample (‰)	δ <sup>13</sup> Cair (‰)	Δ <sup>13</sup> C (‰)
69	Y68 C5	Space B, phase III	weak	Х		CNA1354	$9292 \ \pm 48$	62.94	-24.51	-6.73	18.22
71	X68 C1	Space B, phase III	weak		Х	CNA1354	$9292 \ \pm 48$	61.63	-25.55	-6.73	19.31
73	X68 E1	Space B, phase III	weak	Х		CNA1354	$9292 \ \pm 48$	62.65	-26.57	-6.73	20.37
83	Y68 B4	Space B, phase III	weak		Х	CNA1354	$9292 \hspace{0.1cm} \pm \hspace{0.1cm} 48$	62.73	-25.25	-6.73	18.99
67	Y68 C5	Space B, phase I	weak	Х		CNA1355	$9185\pm40$	63.25	-25.68	-6.72	19.45
70	Y68 E5	Space B, phase I	weak		Х	CNA1355	$9185\pm40$	63.11	-25.96	-6.72	19.75
72	Y68 D5	Space B, phase I	weak	Х		CNA1355	$9185\pm40$	63.09	-24.66	-6.72	18.39
74	X68 E1	Space B, phase I	-		Х	CNA1355	$9185\pm40$	63.95	-25.88	-6.72	19.67
78	X69 A1	Space B, phase I	-	Х		CNA1355	$9185\pm40$	59.09	-26.25	-6.72	20.05
80	X68 D1	Space B, phase I	moderate		Х	CNA1355	$9185\pm40$	61.63	-24.61	-6.72	18.34
88	Y68 B4	Space B, phase I	weak	Х		CNA1355	$9185\pm40$	59.81	-24.86	-6.72	18.60
85	Y68 B4/5	Space B, phase III (pit)	-	Х		CNA1354	$9292\pm48$	64.36	-25.18	-6.73	18.92
11245	BB29	Space A, phase II, roof	-		Х	CNA1065	$9300\pm50$	54.65	-23.55	-6.73	17.23
11244	BB28	Space A, phase II, roof	strong		Х	CNA1065	$9300\pm50$	63.54	-23.61	-6.73	17.28
11212	BB10	Space A, phase II, roof	moderate		Х	CNA1065	$9300\pm50$	60.57	-23.55	-6.73	17.22
11246	BB30	Space A, phase II, roof	-	Х		CNA1065	$9300\pm50$	56.08	-24.25	-6.73	17.95
11238	BB24	Space A, phase II, roof	-	Х		CNA1065	$9300\pm50$	60.97	-23.93	-6.73	17.62
11247	BB31	Space A, phase II, roof	-	Х		CNA1065	$9300\pm50$	60.17	-24.98	-6.73	18.71

Sample Nº	Sample ID	Layer	Growth-ring Curvature	Pistacia sp.	<i>Amygdalu</i> s sp.	Reference	Data BP	%C	δ <sup>13</sup> Csample (‰)	δ <sup>13</sup> Cair (‰)	Δ <sup>13</sup> C (‰)
11248	BB32	Space A, phase II, roof	weak	X		CNA1065	$9300 \pm 50$	59.22	-25.13	-6.73	18.87
11254	BB36	Space A, phase II, roof	moderate	Х		CNA1065	$9300\pm50$	59.74	-23.61	-6.73	17.28
11266	BB43	Space A, phase II, roof	moderate	Х		CNA1065	$9300\pm50$	61.04	-25.37	-6.73	19.12
11274	BB48	Space A, phase II, roof	moderate	Х		CNA1065	$9300\pm50$	62.75	-25.16	-6.73	18.90
11232/3	BB22	Space A, phase II, roof	moderate	Х		CNA1065	$9300 \pm 50$	60.16	-24.79	-6.73	18.51
11218	BB12	Space A, phase II, roof	moderate	Х		CNA1065	$9300\pm50$	61.50	-23.48	-6.73	17.14
11242	BB27	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	59.02	-23.86	-6.73	17.55
11249	BB33	Space A, phase II, roof	weak	Х		CNA1065	$9300 \pm 50$	62.76	-25.27	-6.73	19.02
11263	BB40	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	57.47	-23.65	-6.73	17.32
11267	BB44	Space A, phase II, roof	strong	Х		CNA1065	$9300\pm50$	63.78	-23.22	-6.73	16.87
11250	BB34	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	57.71	-24.12	-6.73	17.82
11220	BB15	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	60.63	-24.46	-6.73	18.17
11253	BB35	Space A, phase II, roof	weak	Х		CNA1065	$9300 \pm 50$	64.27	-24.06	-6.73	17.75

Sample Nº	Sample ID	Layer	Growth- ring Curvature	Pistacia sp.	<i>Amygdalus</i> sp.	Reference	Data BP	%C	δ <sup>13</sup> Csample (‰)	δ <sup>13</sup> Cair (‰)	Δ <sup>13</sup> C (‰)
11228	BB18	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	63.45	-23.31	-6.73	16.97
11234	BB23	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	60.88	-24.35	-6.73	18.05
11193	BB4	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	64.34	-24.08	-6.73	17.77
11277	BB51	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	56.46	-24.00	-6.73	17.69
11265	BB42	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	61.24	-23.01	-6.73	16.65
11279	BB53	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	57.18	-23.86	-6.73	17.55
11260	BB39	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	57.41	-24.42	-6.73	18.12
11214	BB11	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	61.20	-24.22	-6.73	17.92
11278	BB52	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	58.98	-23.55	-6.73	17.22
11256	BB38	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	61.93	-25.02	-6.73	18.76
11273	BB47	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	57.67	-23.97	-6.73	17.65
11275	BB49	Space A, phase II, roof	weak	Х		CNA1065	$9300\pm50$	56.97	-24.22	-6.73	17.92
	BB54	Space A, phase II, roof	strong	Х		CNA1065	$9300\pm50$	56.30	-24.79	-6.73	18.52
	BB55	Space A, phase II, roof	moderate	Х		CNA1065	$9300 \pm 50$	57.32	-23.64	-6.73	17.32

**Table S3.** Carbon isotope discrimination ( $\Delta^{13}$ C, ‰) of the charcoal remains recovered in different phases of the Space A (area XYZ) and classified attending their degree of growth-ring curvature. Values presented are means ± SD. Comparisons were performed only for those phases where charcoals from the same genus and different curvatures were recovered as detailed in Table S2. Samples from phases II (Roof) and IV belong to *Pistacia* sp., whereas samples from phases V and VI are of *Amygdalus* sp. Differences across categories of charcoals were tested with ANOVA.

Growth-ring Curvature	Phase II (Roof)	Phase IV	Phase V	Phase VI
Weak	$17.74\pm0.60$	$18.61\pm0.24$	$18.44 \pm 0.21$	$18.21\pm0.52$
Moderate	$18.05\pm0.91$	/	/	$19.54\pm0.27$
Strong	$17.69 \pm 1.16$	$17.93 \pm 1.25$	$19.07\pm0.50$	/
Level of significance	0.654 <sup>ns</sup>	0.395 <sup>ns</sup>	0.252 <sup>ns</sup>	0.086 <sup>ns</sup>

Area	Sample	Phase	Phytoliths 1 g of	Phytoliths	Multicelled	Description
	number		sediment (million)	weathering (%)	phytoliths (%)	
XYZ- 67/68/69	8	V	1.19	5.6	2.3	Dark very fine ashy powdery clayey silt without clasts, including flint, bone and pottery.
	12	IV	1.3	6.2	1.6	Dark very fine ashy powdery clayey silt. The matrix is similar to unit 3, with few scattered small rounded basalt clasts and randomly scattered larger stones. The dominant colour is dark greyish brown.
	16	IV	1.3	3.9	6.6	Dark very fine ashy powdery clayey silt, small rounded basalt clasts and abundance of randomly scattered larger stones.
	Base 2009, 1	III	2	5.4	10.9	Almost exclusively reddish yellow adobe compounds, embedded in a fine matrix of similar colour.
	Base 2009, 1 out	III	1.3	7.5	0.9	Reddish yellow adobe compounds.
	29	Π	2.6	1.2	42.3	Ashy with large fragments of charcoal, including carbonized wooden elements, heavily burned adobe and non-wooden plant remains.

Table S4. Provenance, description of samples and main phytolith results obtained from excavation areas XYZ and VU at Tell Qarassa North.

	33	Ι	1	9.1	6.9	Massive homogeneous pulverised reddish yellow adobe including decimetric angular basalt clasts and small basalt clasts.
VU-67	1		1.7	5.2	2.4	Compact clay sediment.
	3		1.2	9.6	2	Clayey silt with small basalt clasts, greyish brown colour.
	5	V	0.84	7.1	0.9	Powdery clayey silt, brown colour.
	8	V	1.4	5.1	4.1	Powdery clayey silt, similar to US 3 but darker.
	10	V	0.72	7.2	0	Powdery clayey silt, similar to US 3 but darker.
	11	V	1.3	9.1	7.3	Dark gray ashy sediments, including adobe compounds.
	12	IV	0.88	8.6	9.1	Yellowish brown sediments, including adobe fragments, ashes, charcoal, bone and lithic artefacts.
	18	IV	0.97	7.9	3	Yellowish brown sediments, including adobe fragments, ashes, charcoal, bone and lithic artefacts.
	EF18-1	IV	1.1	7.9	1.8	Burial EF18, close to cranial remains.
	EF18-2	IV	0.74	6.7	1.2	Burial EF18, under the pit base.
	21	IV	0.95	6.6	2.4	Clayey matrix sediments and basalt clasts, with abundant ashes charcoal fragments, bone and lithic artifacts.

**Table S5.** Summary of the early Holocene wood charcoal records in southwest Asia. Numbers represent percentage fragment counts by taxa. In some cases the raw datasets were not available, and the presence of taxa was recorded with an X. "Small shrubs" comprise steppic taxa such as *Artemisia, Acacia, Atriplex, Paliurus* etc. "Others" represent rare taxa (e.g., *Vitis*, Leguminosae), as well as cf. identifications of taxa not included in the table (e.g. cf. Labiatae). *Quercus* (E, D) means *Quercus* evergreen and deciduous respectively. Total fragments were calculated excluding indeterminate wood charcoal fragments.

Site		Wadi Faynan 16 12 6-	Gilgal I (PPNA)	Öküzini (Ia)	Körti k Tepe 11 7-	Jerf el Ahmar
Date ka cal. BP		10.2	11.5-11.1	11.6-9.3	11.4	11.4-10.7
Salicaceae		15.5	22.8		X	26.0
Ficus		6.3				
Platanus	Wetland					0.7
Fraxinus				x	x	12.1
Vitex						
Tamarix		7.1	50.9	cf.	x	9.5
Chenopodiaceae	Ctown or and	4.0	8.8			3.7
Ephedra	Steppe and	0.1				
Small shrubs	naiopitytes					0.7
Capparis		1.4				
Pistacia		3.2	7.0	x	x	14.3
Amygdalus	W7			cf.	x	19.0
Rosaceae	woodland					1.8
Rhamnus	/steppe			x	x	4.4
Maloideae						
Juniperus		57.5				
Celtis/Ulmus					x	0.4
Olea	Oak/junip					
<i>Quercus</i> (E/D)	er					
<i>Quercus</i> (E)	woodland	2.2		x		
<i>Quercus</i> (D)				x	x	5.5
Acer				x	x	
Pinus	Coniferou	0.1				
	S					
Cedrus	woodland					
	Others	2.7	10.5			1.8
Total fragm	nents	2539	57	204	1487	273
		Austin, 2007	Liphschitz, 2010	Emery- Barbier and Thiébault, 2005	Riehl et al., 2012	Roitel, 1997 (see also Pessin, 2004)

Site		Mureybet (phase III- IV)	Göbekli Tepe 11.2-	Baaz (II- III)	el- Hemmeh PPNA	Jericho (I) 11.1-
Date ka cal. BP		11.3-10.5	10.6	11.1-10.2	11.1-10.7	10.3
Salicaceae		x		91.0	7.5	15.2
Ficus					3.9	20.9
Platanus	Wetland					
Fraxinus		x			1.6	
Vitex						0.4
Tamarix		x			0.6	49.4
Chenopodiaceae	Stanna and				7.2	
Ephedra	steppe and					
Small shrubs	naiopitytes				1.7	9.5
Capparis					cf. 0.2	0.4
Pistacia			63.4		70.6	
Amygdalus			cf. 36	6.1	2.0	
Rosaceae	Woodland/steppe				0.8	
Rhamnus					0.6	
Maloideae					0.2	
Juniperus				3.0		
Celtis/Ulmus						
Olea						0.4
<i>Quercus</i> (E/D)	Oak/juniper					2.7
$\tilde{Q}$ uercus (E)	woodland				3.0	
$\tilde{Q}$ uercus (D)		x	0.6			
- Acer						
Pinus	Coniferous					
Cedrus	woodland					
	Others					1.1
Total fr	agments	-	164	907	636	c. 263
	0	Table 7 in Roitel, 1997 (after Willcox)	Neef, 2003	Deckers et al., 2009	Asouti et al., 2015	Western, 1983

Site		Chogha Golan (XI-VII)	Pinarba și (A) 10.7-	Dja'de	Horvat Galil	Mureybet (phase IV) 10.7-
Date ka cal. BP		11.9-10.7	10.5	10.7-10.3	10.7-9.9	9.9
Salicaceae		33.5		37.3		
Ficus						
Platanus	Wetland			2.0		
Fraxinus				9.7		
Vitex		0.3				
Tamarix		23.5		33.3		
Chenopodiaceae	Ctown or and	2.0	1.6	4.6		
Ephedra	Steppe and					
Small shrubs	natophytes	0.3	4.9	0.7		
Capparis						
Pistacia		34.3	1.6	6.8	66.6	
Amygdalus	<b>XX</b> 7 <b>11</b> 1/	2.8	32.8	0.6		
Rosaceae	Woodland/s		55.7	0.5		
Rhamnus	teppe			0.5		
Maloideae						
Juniperus						
Celtis/Ulmus						
Olea					16.7	
<i>Ouercus</i> (E/D)	Oak/juniper					
Quercus (E)	woodland				16.7	
Quercus (D)				3.0		х
Acer		0.3		0.4		
Pinus	Coniferous					
Cedrus	woodland					
	Others	3.1	3.3	0.4		
Total fragr	nents	391	61	1116	6	_
		Riehl et al., 2015	Asouti, 2003	Roitel, 1997	Liphschitz, 1997	Table 7 in Roitel 1997, after Willcox

Site Date ka cal		Tepe Abdul Hosein	Cafer Höyük	Nahal Zippori 3	´Ain Ghaza l 10 3-	Çatalhöy ük (South G)
BP BP		10.3-9.8	10.3-9.4	10.2-9.9	8.6	8.4
Salicaceae		x	x		x	29.7
Ficus				3.7		
Platanus	Wetland		x			
Fraxinus			x			0.2
Vitex						0.2
Tamarix		x			X	0.3
Chenopodiace		x				0.5
ae	Steppe and					
Ephedra	halophytes					
Small shrubs						
Capparis				2.2		2.0
Pistacia		x	x	3.3	X	2.9
Amygdalus	Woodland/step					2.1
Rosaceae	pe	x	x			0.4
Rhamnus	_		X			1.0
Maloideae						1.8
Juniperus						0.7
Celtis/Ulmus			X			30.8
Olea	Oal:/iuninar					
(E/D)	Woodland			18.9		
$(\mathbf{L}/\mathbf{D})$	woodiand			74 1	r	
Quercus(D)			r	/ 1.1	x x	2.4
Quereus (D) Acer			x		20	2.1
Pinus	Coniferous					
T utus Cedrus	woodland					
ceurus	Others					2.1
Total fr	agments	-	_	615	-	1311
	0	Willcox	Willcox	Caracuta et	Neef,	Asouti,
		, 1990	, 1991	al., 2014	2004a	2013

			el- Hemmeh	Jericho	Tell Aswa	Chogha Golan
Site		Ganj Dareh	PPNB	(II)	d II	(VI-I)
Date ka cal.				10.2-	10.2-	
BP		10.2-9.8	c. 10-9	9.5	9.5	10-9.6
Salicaceae		x	20.5	7.9	11.7	33.3
Ficus			9.0	4.9		
Platanus	Wetland			0.5		
Fraxinus			34.7	7.4	29.7	
Vitex				0.5		
Tamarix			14.7	53.2	44.4	20.8
Chenopodiace			63		21	15
ae	Steppe and		0.0		2.1	1.0
Ephedra	halophytes					
Small shrubs			1.3	2.0		0.7
Capparis				3.4		
Pistacia		X	6.3		1.3	39.1
Amygdalus	Woodland/sten		1.1	1.0		2.3
Rosaceae	ne	x	0.8			0.1
Rhamnus	pe	x		0.5	0.4	
Maloideae			0.5			cf. 0.1
Juniperus						
Celtis/Ulmus		?				
Olea						
Quercus	Oak/juniper			0.5		
(E/D)	woodland			0.5		
<i>Quercus</i> (E)			0.6			
Quercus (D)						
Acer						
Pinus	Coniferous					
Cedrus	woodland				0.4	
	Others		4.0	18.2	10.0	2.1
Total fr	agments	-	619	c. 203	478	809
		van Zeist et	Asouti et	Wester	Pessin	Riehl et
		al., 1984	al., 2015	n, 1983	, 2004	al., 2016

		Con Hosson	Tell Halula	
Site		III	(IVI/L PPNB)	Basta
Date ka cal. BP		9.7-9.4	9.8-9.3	9.5-9.0
Salicaceae		x	23.9	x
Ficus				
Platanus	Wetland		1.2	
Fraxinus			14.2	x
Vitex				
Tamarix			30.6	x
Chenopodiaceae			2.6	
Ephedra	Steppe and			
Small shrubs	nalophytes		0.7	
Capparis				
Pistacia		x	11.0	x
Amygdalus		x	1.9	x
Rosaceae	Woodland/steppe		0.2	
Rhamnus				
Maloideae				
Juniperus		x		x
Celtis/Ulmus		x	2.2	
Olea				
Quercus (E/D)	Oak/juniper			
Quercus (E)	woodland			x
Quercus (D)		x	8.1	
Acer			0.6	
Pinus	Coniferous	x		
Cedrus	woodland			
	Others		0.6	
Total fr	agments	-	2322	-
		Willcox,		
		1991,	Roitel,	Neef,
		Figure 2, p.	1997	2004b
		142		

41 Table S6. Faunal remains from excavations areas XYZ at Tell Qarassa North (NISP:

<sup>42</sup> number of identified specificens). Bone tools were excluded from the count	42	number of identified specime	ns). Bone tools were	e excluded from the count
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	Area	a XYZ	Z				Area V	U U		
									Surf	
Taxa							Lowe	Uppe	ace	Total
	I	II	III	IV	$\mathbf{V}$	VI	r	r	lave	
									rs	
Vulpes sp.	5	11	38	18	12	3	26	1	2	62
Meles meles			6	1	3					4
Felis silvestris		2	5		1		3			4
Canis familiaris			8	1	2	1				4
Carnivore	5	2	27	C	11		12	1	2	22
unidentified	5	Ζ	27	0	11		15	1	Z	33
Sus f. scrofa			5	1	1	1	13		2	18
Dama mesopotamica			1	1	2				1	4
Bos f. primigenius	2	2	22	16	7	24	5	8	2	62
Large ungulate	1	1	1	16	37	7	3	5	9	77
Gazella ssp.	15	8	89	38	61	23	67	21	12	222
Capra f. aegagrus	15	1	7	27	49	1	38	12	2	129
Capra/Ovis	18	15	15	46	74	18	59	9	14	220
Small ungulate	3	34	232	75	181	21	14	16	18	325
Lepus capensis	2	3	25	6	12	2	8	4		32
Erinaceus concolor			1							0
Anas acuta	1									0
Anas platyrhynchos	1		3		5	1		1	2	9
Anas crecca			1		1					1
А.					1			1		2
crecca/querquedula					1			1		2
Anatinae unidentified			4		2		1			3
Aquila f. chrysaetos							1			1
Accipitridae		1								0
Alectoris chukar		1	11	1	3	1	5			10
Rallidae			1							0
Otis tarda				1						1
Corvus corone			1		1					1
Birds unidentified	2	1	9	5	4		4			13
Total NISP	101	94	706	264	558	113	409	82	102	1528

Figure S1. Summary of early Holocene pollen (black circles) and wood charcoal (black 48 squares) records (based on Table S5, excluding riparian taxa) in relationship to modern-49 day phytogeographical regions in southwest Asia (schematic representation based on 50 vegetation maps by Frey and Kürschner, 1989). Dark orange: Irano-Turanian arid steppe; 51 Grey: Irano-Turanian deciduous steppe and open parkland. Light orange: Saharo-Arabian 52 semi-desert vegetation. Yellow: Sudanian desert. Light green: Mediterranean maquis; 53 Turquoise: Mediterranean evergreen and deciduous oak forests; Dark green: coniferous 54 forests. 1. Basta; 2. Wadi Faynan 16; 3. El-Hemmeh; 4. Jericho; 5. Gilgal I; 6. Ain Ghazal; 55 7. Nahal Zippori 3; 8. Horvat Galil; 9. Tell Qarassa North; 10. Tell Aswad: 11. Baaz 56 Rockshelter; 12. Mureybet; 13. Dja'de; 14. Jerf el Ahmar; 15. Tell Halula; 16. Göbekli 57 Tepe; 17. Körtik Tepe; 18. Cafer Höyük; 19. Can Hassan III; 20. Catalhöyük; 21. Öküzini 58 Cave; 22. Pinarbaşi; 23. Ganj Dareh; 24. Tepe Abdul Hosein; 25. Chogha Golan. I. Ein 59 Gedi (Litt et al., 2012); II. Hula pollen core (van Zeist et al., 2009); III. Birkat Ram Crate 60 (Schiebel, 2013): IV. Aamiq wetland (Hajar et al., 2008); V. Ghab (Wright and Thorpe, 61 2003); VI. Eski Acigöl (Roberts et al., 2001); VII. Akgöl (Bottema and Woldring, 1984); 62 VIII. Lake Van (Wick et al., 2003); IX. Lake Urmia (Djamali et al., 2008b); X. Lake 63

64 Zeribar (van Zeist and Bottema, 1977); XI. Lake Mirabad (van Zeist and Bottema, 1977).



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