

## **Title**

Changing Land Use and Political Economy at Neolithic and Bronze Age Knossos, Crete: Stable Carbon ( $\delta^{13}\text{C}$ ) and Nitrogen ( $\delta^{15}\text{N}$ ) Isotope Analysis of Charred Crop Grains and Faunal Bone Collagen

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## **Abstract**

Excavations at Knossos have uncovered faunal and archaeobotanical archives spanning the Neolithic and Bronze Age (7<sup>th</sup> to 2<sup>nd</sup> millennia BCE), during which one of Europe's earliest known farming settlements developed into its first major urban settlement and centre of one of its oldest regional states. Through stable isotope ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ ) analysis of seeds and bones (as evidence for the growing conditions of cereal and pulse crops and for the types of forage consumed by livestock), land use and, ultimately, political economy are explored. Changing husbandry conditions overwrite any effects of long-term aridification. Early (7<sup>th</sup>-6<sup>th</sup> millennium BCE) Knossian farmers grew intensively managed cereals and pulses (probably in rotation) that were closely integrated (as manured sources of forage) with livestock. Through the later Neolithic and Bronze Age, settlement growth accompanied more extensive cultivation (eventually with cereals and pulses not in rotation) and greater use of rough graze and, by goats, browse. Pasture on cultivated land remained central, however, to the maintenance of sheep, cattle and pigs. Variable diet of early sheep suggests management at the household level, while thereafter progressive dietary divergence of sheep and goats implies their separate herding. Until the Old Palace phase (early 2<sup>nd</sup> millennium BCE), urban growth was matched by increasingly extensive and probably distant cultivation and herding, but somewhat more intensive conditions during the New and Final Palace phases (mid-2<sup>nd</sup> millennium BCE) perhaps reflect greater reliance on surplus from prime land of previously rival centres that now came under Knossian control.

## **Key words**

Knossos, Neolithic, Bronze Age,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , crop husbandry, pasture, sheep, goats

## **Running head**

Stable isotopes, land use and political economy at Neolithic-Bronze Age Knossos

## Text

In memoriam: John D. Evans, Sinclair Hood, Mervyn Popham

### INTRODUCTION

The emergence of urban settlements and strongly hierarchical societies in later prehistoric southwest Eurasia placed considerable demands on the production and mobilisation of food, triggering extensive scholarly debate on related changes in crop and livestock husbandry (eg, Childe 1950; Renfrew 1972; Gilman 1981; Sherratt 1983; Halstead 1992; Wilkinson 1994). The ERC-funded AGRICURB project has combined stable carbon and nitrogen isotope analysis of crop seeds and domestic animal bones to shed new light on farming methods in contexts ranging from the Neolithic to Iron Age and from northern Mesopotamia (Styring *et al.* 2017), through northern Greece (Nitsch *et al.* 2017) to central Europe (Styring *et al.* 2018). As a further outcome of this project, here we apply these methods to Knossos on Crete, southern Greece (Fig. 1), presenting the first such results from the site for faunal samples and new data for crop seeds, building on those reported by Nitsch *et al.* (2019) and Styring *et al.* (in press). Knossos is one of the earliest known farming settlements, earliest major urban settlement, and centre of one of the oldest regional (Minoan and Mycenaean) states in Europe (eg, Cadogan *et al.* 2004; Isaakidou & Tomkins 2008). Occupied from the early 7th to 1st millennia BCE, it offers the longest diachronic archive in Europe of domestic animal and crop remains and thus an exceptional opportunity to explore the relationship of settlement growth and state formation to changing husbandry practices.

Drawing on macroscopic analysis of these archaeobotanical and faunal archives and on palatial written documents, previous studies have sought to reconstruct aspects of crop and livestock husbandry at 7th-2nd millennia BCE Knossos and of resource mobilisation by its 2nd millennium BCE 'palace'. Here we test and refine these piecemeal and largely circumstantial reconstructions using direct evidence for husbandry conditions of 7th-2nd millennia BCE Knossian crops and livestock, based on stable carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) isotope analysis of their seeds and bones.

### BACKGROUND

### *Knossos: from farming hamlet to urban palatial centre*

Excavation and surface survey (Evans 1971; Hood & Smyth 1981; Whitelaw *et al.* 2019) have elucidated the growth of Knossos (Table 1). An Initial (IN) and Early (EN) Neolithic hamlet of perhaps 30 inhabitants developed through the Middle (MN), Late (LN) and Final Neolithic (FN) into a village of up to 250 (Tomkins 2008) or even 450 head (Whitelaw 2012, 147-8; Legarra Herrero 2019). Thereafter a suggested 'Prepalatial' (PreP) nucleated settlement of 1000-1300 grew rapidly to 4-10,000 in the 'Late Prepalatial' (LPreP), 12,500-15,000 in the 'Old Palace' (OP) and 15-25,000 in the 'New Palace' (NP), before contracting to 12,000 in the 'Final Palace' (FP) and perhaps less than 3000 in the 'Postpalatial' (PostP) phase (Cutler & Whitelaw 2019, 15; Hatzaki 2017). It is debated (as for mainland Greece) whether 'households' emerged early or late in the Neolithic at Knossos, where intelligible architecture is sparse, and the balance between domestic and collective control of resources was probably contested (Halstead 1995; 2019; Tomkins 2004; Kotsakis 2006). The earlier Neolithic community was small enough for egalitarian maintenance of social cohesion (cf. Forge 1972; Broodbank 1992, 42), but, from the PreP (if not later Neolithic), Knossos exceeded this limit (Legarra Herrero 2019) and the ancient core of the settlement was segregated for public or elite use (Tomkins 2012), including the later 'palaces' (cf. Whitelaw 2001).

At the inter-site level, Knossos was too small for a viable breeding population in the earlier Neolithic (Isaakidou 2008, 102; Tomkins 2008, 30-1), but had achieved potential demographic self-sufficiency by the PreP and conceivably by the later Neolithic. Ideological or economic pre-eminence of later Neolithic Knossos over the tiny settlements then widespread in the landscape (Tomkins 2008; 2020) cannot be excluded, but Knossian dominance of a regional hierarchy is first evident in the palatial period. The numerous FP Linear B texts reveal selective Knossian palatial control and exploitation of agricultural, pastoral and craft production across the central third or half of Crete (Bennet 1988; Godart 1977; Killen 1977; Halstead 1999a). Earlier (OP-NP) Hieroglyphic and Linear A texts, documenting similar resources (eg, Palmer 1995), are few and enigmatic (Bennet 2008), while some centres later subordinate to FP Knossos probably headed independent OP-early NP polities (Bennet 2012; Whitelaw 2019). The size of OP-NP urban Knossos, however, suggests its inhabitants already drew substantial resources from well beyond their immediate catchment (eg, Whitelaw 2004, 155 fig. 10.6; 2019).

The following section outlines previous models, and their underpinning evidence, of 7th-2<sup>nd</sup> millennia BCE land use and 2nd millennium BCE palatial resource mobilisation at Knossos, as a prelude to their evaluation in the light of stable carbon and nitrogen isotope analyses of ancient crop seeds and animal bones. In conclusion, we explore how resulting insights into past land use may enrich understanding of social change at Knossos.

*From archaeobotanical and faunal archives and textual records to models of changing land use*

Crete has a Mediterranean climate of mild wet winters and hot dry summers, with considerable inter-annual variability in precipitation. Knossos in lowland central Crete, with annual rainfall over the last century ~500 mm (Tsiros *et al.* 2020), experiences more severe summer drought than most of mainland Greece (eg, Isaakidou 2008, 100 fig. 6.3). Proxy records across the Aegean and Mediterranean indicate a long-term trend to greater aridity through the 7<sup>th</sup>-2<sup>nd</sup> millennia BCE, punctuated by regionally variable (Finné *et al.* 2019) cold and dry episodes towards the end of the seventh, possibly fifth, and third millennia BCE, although their timing, nature and severity are debated (eg, Aufgebauer *et al.* 2012; Clarke *et al.* 2016; Dormoy *et al.* 2009; Giamali *et al.* 2019). Both long- and shorter-term changes (cf. Mauri *et al.* 2015, fig. S3) could influence the carbon and nitrogen isotope values (both generally raised by aridification) of plants and herbivorous fauna, but the principal climatic constraints on Cretan vegetation – summer drought, coupled with winter frost in the uplands – are relevant throughout this period.

The uncultivated vegetation of Crete (Zohary & Orshan 1965; Rackham & Moody 1996, 109-22) comprises a mosaic of herbaceous plants, dwarf shrubs (*phrygana*) and, below a variable tree-line, mainly broad-leaved evergreen and deciduous arboreal species (shrubs more than trees). Significant factors shaping the herbaceous-dwarf shrub-arboreal mosaic are summer drought (reflecting climate, topography and geology), human clearance and especially (as protective enclosures confirm) grazing/browsing by livestock. Neolithic inhabitants faced richer vegetation, judging by evidence for deciduous oaks in pollen cores from lowland south-central and northwest Crete (Bottema 1980; Bottema & Sarpaki 2003) and in charcoal from the earliest occupation at Knossos (Badal & Ntinou 2013). Of particular relevance to carbon isotope values in animal bone, Cretan vegetation is heavily dominated by plants with C<sub>3</sub> photosynthesis (and thus relatively low  $\delta^{13}\text{C}$  values). C<sub>4</sub> plants (with higher  $\delta^{13}\text{C}$  values) are today restricted to a few crops (all or most being historical introductions), to summer weeds and ruderals in gardens or

harvested fields or disturbed ground (Bergmeier 2008), and to saline coastal rough pasture (cf. Le Houérou 1994; Dimopoulos *et al.* 2012, 84 table 1); local tectonic and alluvial changes (eg, Ghilardi *et al.* 2018) will have affected the past extent of saline pasture. Around Knossos itself (Roberts 1979), limestone ridges immediately north and 5 km south of the settlement traditionally provided wet-season grazing, but the dominant marls will have supported woodland offering year-round browse until Neolithic clearance expanded seasonal grazing on cultivated land.

The distinctive insular fauna of Pleistocene Crete became extinct before the 7<sup>th</sup> millennium BCE introduction of domesticates (Jarman 1996) and the only large ‘wild’ terrestrial animals today are feral (escaped domestic) goats, widespread on inaccessible rocky terrain (eg, Xanthoudidis 1918, 272, n. 3, 4). 2<sup>nd</sup> millennium BCE figurative art apparently represents feral goats (eg, Vanschoonwinkel 1996), while biometric analysis of Knossos faunal remains may indicate feral goats and pigs by the later Neolithic (Isaakidou 2005). Badger was introduced during the Neolithic and European fallow deer during the Bronze Age (Jarman 1996; Isaakidou 2005), but the latter were conceivably enclosed, as argued by Hubbard (1995; also Palmer 2012, 380-1) for mainland Greece, rather than free-range.

The archaeobotanical archive is relatively sparse, with early excavations in the palace reporting but not retaining stored grain (Halstead 1992, 108 table 1). Of available material, a range of FP cereals and pulses comes from Storeroom P in the elite ‘Unexplored Mansion’ (Jones 1984; Fig. 2), while earlier samples derive from more diverse and socially inclusive contexts. At Knossos, as elsewhere on Crete, cultivated cereals and pulses were consumed throughout the period under review (Sarpaki 2013) and, in the NP and FP phases at least, included several species of both crop types (Sarpaki 2012; Livarda & Kotzamani 2013; Sarpaki & Jones 1990). Additionally, charred pips/stones, wood charcoal and pollen suggest increasing exploitation of olive (Valamoti *et al.* 2018) and vine (Sarpaki 2012) on Crete from the PreP phase onwards and perhaps of almond at Knossos itself from the later Neolithic (Badal & Ntinou 2013; Sarpaki 2013). Lastly, two C<sub>4</sub> crops were *possibly* present on palatial-era Crete: common millet, *Panicum miliaceum*, is well represented archaeobotanically in northern Greece (Valamoti 2016) but not certainly on Crete (Livarda & Kotzamani 2013); and the commodity CYP, listed in Linear A and associated in Linear B with feasting/offerings, perfumery and possibly also fodder, is plausibly translated as

tiger nut, *Cyperus esculentus* or wild *C. rotundus* (Melena 1974), and starch grains attributed to the former are reported from palatial-era ceramic vessels on Crete (Tsafou & García-Granero 2021).

The excavated faunal archive from IN-LPreP Knossos derives from both domestic and communal contexts, but public/elite areas are overrepresented in the OP-FP assemblages. Domestic cattle, goat, sheep and pig dominate throughout, while dog, badger and, from the NP phase, horse and fallow deer are relatively scarce (Isaakidou 2005; 2008).

Knossian land use was shaped by its southern Aegean setting and the community's changing size, internal organisation and regional integration. Models of ancient land use in Greece have often drawn analogies with traditional 'extensive' (low-input) farming, tacitly assuming shared limitations of technology and knowhow (Halstead & Isaakidou 2020). Most Neolithic settlements, however, including earlier and perhaps also later Neolithic Knossos, were small enough to have been sustained by cultivation within a few minutes' walk and thus potentially by labour-intensive, high-yielding husbandry with cereal-pulse rotation, manuring and weeding (Halstead 1981a). Subsequent settlement growth, necessitating cultivation of more distant and less fertile land, will have impeded intensive husbandry, albeit perhaps partly offset by using cattle for tillage and bulk transport (Isaakidou 2008; Whitelaw 2012, 162-3).

Palatial Knossos drew resources from a broad region by a combination of staple and wealth finance, issuing rations of staple grains to hundreds of craft workers whose fine finished products were exchanged for other goods and services (eg, Killen 2008; Bennet & Halstead 2014). To account for production of the underpinning 'surplus' grain, both intensification (Gilman 1981; Renfrew 1982) and extensification (Halstead 1992; Whitelaw 2019, 97-98) have again been invoked, with a combination of archaeobotanical, textual and iconographic evidence cited in support of the latter. In the palatial phases on Crete, although charred grains include multiple pulse and cereal species, Hieroglyphic, Linear A and Linear B texts apparently record no pulses and only two (in Linear B, conceivably three) cereals (Palmer 1995; 2008; Halstead *et al.* in press). Moreover, the Linear B texts refer to production/collection of just one cereal (Killen 1995), conventionally identified as 'wheat'. FP Knossian scribes recorded its receipt in large quantities at subordinate centres (Bennet 1985) and it was arguably grown with extensive methods such as regular fallowing and tillage by oxen, the latter apparently loaned by the palace

(Killen 1993), under some form of share-cropping (Halstead 1999b). While textual evidence from the earlier palaces is sparser, the NP 'Harvester Rhyton', depicting a large gang of winnowers (Fig. 3a), suggests that extensive agriculture and share-cropping (Halstead & Isaakidou 2021) may likewise have contributed to filling large-scale storage facilities (eg, Christakis 2008; Privitera 2014; Fig. 3b) and financing elites. The case for palatial production of surplus 'wheat' by extensive methods rests on circumstantial evidence, however, while the contrast between specialised textual and diverse archaeobotanical records implies that palatial-era pulses and some/most cereals were produced on a different institutional basis and so potentially with more intensive husbandry (cf. Nitsch *et al.* 2019).

Throughout the Neolithic at Knossos, male sheep, goats and cattle were slaughtered young, favouring meat yields over specialisation in milk, fibre or traction, although skeletal 'pathologies' indicate yoking of female cattle for draught. Conversely, prepalatial Bronze Age sheep, goats and cattle and palatial-era sheep and goats lived longer and far more males (especially of sheep) reached adulthood, consistent with greater emphasis on wool, hair and traction, but also with selection of large adult males for conspicuous consumption in public/elite contexts (Isaakidou 2006). FP texts list working oxen and numerous wool-bearing male sheep (Fig. 3c), although it should be noted that *regional-scale husbandry* records may be unrepresentative of animals *consumed at Knossos*.

As with crop growing, alternative models of Neolithic animal keeping have proposed contrasting scales of livestock husbandry. Proponents of extensive husbandry have emphasised the scarcity of summer grazing in the lowlands (eg, for Knossos, Jarman *et al.* 1982, 147), arguing for seasonal use of upland pastures and tacitly assuming sufficient numbers of livestock to warrant such mobility. Conversely, in a largely uncultivated landscape better suited to cattle, goats and pigs, the dominance of sheep at IN-MN Knossos (and other earlier Neolithic settlements in Greece) might reflect their close integration with cultivated land and thus maintenance in small numbers – especially so if crops were grown intensively on a small scale (Halstead 1981a; Isaakidou 2008; Halstead & Isaakidou 2020). During LN-FN, sheep remained dominant, but gave way somewhat to cattle, some at least used for draught (Isaakidou 2008; 2011), and less so to goats (Isaakidou 2008, 95 fig. 6.2). The proportional increase in goats, and their high frequencies at later Neolithic and younger sites colonising agriculturally marginal areas

elsewhere on Crete (eg, Petras-Kefala, Priniatikos Pyrgos, Schinokapsala, Trypiti – Molloy *et al.* 2014; Isaakidou in prep.; Fig. 1), may reflect greater reliance on browse beyond the cultivated area. Moreover, even if Knossian livestock numbers expanded only in step with community size, economies of scale (Halstead 1996) would potentially have facilitated separate herding of sheep and goats on grazed and browsed pasture, respectively. Pigs too could have exploited woodland browse and pannage (Jarman & Jarman 1968, 260-1) and/or, as recently in northern Greece, stubble and fallow fields (Halstead & Isaakidou 2011), but in small numbers may largely have consumed crop by-products and food waste around the settlement. Rough (ie uncultivated) pasture suitable for cattle was probably scarcest, but these large animals were better able than sheep, goats or pigs to survive on coarse straw and stubble, perhaps supplemented by grain when their use for work prevented grazing (eg, Halstead 2014, 50-3). Dogs routinely gnawed the bones of other domesticates and so consumed at least their marrow (Isaakidou 2005), but were perhaps fed mainly with cultivated grain (or, like recent herders' dogs, bran) unless livestock were slaughtered very regularly (and thus herded on a large scale).

Through the palatial phases, urban Knossos with its monumental 'palace' probably drew livestock as well as agricultural produce from subordinate settlements, as textual (Godart 1971) and faunal isotopic (Isaakidou *et al.* 2019) evidence confirms for the FP phase. Such flows may account for the high representation in Bronze Age faunal assemblages from Knossos, compared with other sites on Crete, of cattle (Halstead & Isaakidou 2017), the largest and, in elite iconography (eg, Blakolmer 2016), most prestigious common domesticate. Livestock and their products/services dominate FP texts (Halstead 2002), that record palatial interest in goats, pigs, cattle (including working oxen) and especially male sheep and wool across central Crete. Texts also list animals earmarked for consumption, some after 'fattening' or 'finishing' (Killen 1994; 1999), but offer no indication of where livestock were pastured (Bennet 1985). Indeed, selective coverage (eg, listing too few breeding ewes to re-stock recorded flocks) suggests concern with palatial rights to wool rather than animal husbandry *per se* (Halstead 2001). Nonetheless, the apparent concentration of recorded sheep at toponyms with extensive arable land suggests a major role for stubble and fallow fields (Halstead 1981b, 204), while total numbers (probably exceeding 80,000 – Killen 1964) invite speculation that (like recent dairy flocks) they grazed mountain pastures in summer, as confirmed for some FP sheep, but not goats, by incremental analysis of oxygen and carbon stable isotopes in tooth enamel carbonate (Isaakidou *et al.* 2019).

Despite palatial interest in large-scale herding, especially of wool flocks, a few 'household' pigs, goats or sheep could have been raised intensively throughout the Neolithic and Bronze Age, and even by palatial-era elite households for their day-to-day provisioning on which the texts are silent. Recent farmers of moderate means widely kept such animals for domestic consumption of preserved pork and cooking fat, young kids/lambs, and milk/cheese (Halstead 1996; Halstead & Isaakidou 2011).

While macroscopic archaeobotanical and faunal data from Knossos shed direct light on the crop and livestock species exploited over time and on the relative abundance and uses of the latter, they offer at best very indirect hints as to the scale and intensity of husbandry or the degree of integration between crops and livestock. For the palatial era, texts add a wealth of contextual detail for the husbandry and consumption especially of livestock and their products, and document the farming of wheat and sheep, at least, on a very large scale. The texts provide a highly selective, elite-centred perspective, however, and again shed limited light on how the recorded crops and livestock were raised. Accordingly, rival models of land use offer very different visions of the scale, intensity and integration of Knossian land use and of the production of the staple resources that financed its palatial elite. The remainder of this paper seeks to resolve these uncertainties, using stable isotope data to clarify the conditions under which grain crops and livestock were raised at Knossos and thus the scale, intensity and integration of land use.

## CHANGING LAND USE: IMPLICATIONS FOR $\delta^{13}\text{C}$ AND $\delta^{15}\text{N}$ VALUES OF GRAIN CROPS AND LIVESTOCK

Supplementary text S1 sets out the methodological background for interpretation of  $\text{C}_3$  grain crop  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in relation to changing land use. Hypothesised intensive early crop husbandry (see above) on the water-retentive soils of the Knossos valley should be associated with relatively low grain  $\delta^{13}\text{C}$  values indicative of well-watered conditions, especially if the Kairatos stream was channelled for small-scale flood-irrigation (as latterly for market-gardens). Subsequent expansion onto more distant and poorer/less thoroughly tilled land should be matched by lower water availability and higher  $\delta^{13}\text{C}$  values. High cereal  $\delta^{15}\text{N}$  values should

characterise (earlier) Neolithic intensive husbandry close to Knossos, declining in the later Neolithic or prepalatial Bronze Age as cultivation over greater distances, albeit apparently facilitated by draught cows, enforced more extensive methods. In the palatial Bronze Age, low  $\delta^{15}\text{N}$  values are expected for 'wheat' grown extensively, but other grains, production of which is not recorded textually, might exhibit higher values if grown more intensively.

Supplementary text S2 and Fig. S1a-b set out the methodological background for interpretation of animal bone collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in relation to changing land use. If the earliest Knossian livestock were closely tied to cultivated land on intensively managed water-retentive soils (above), their diet may have exhibited a narrow  $\delta^{13}\text{C}$  range and relatively high  $\delta^{15}\text{N}$  values. From the later Neolithic onwards, if more numerous livestock exploited more distant and diverse pasture, with different species herded separately, broader dietary  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  ranges would be expected, with greater divergence between species and generally lower  $\delta^{15}\text{N}$  values. Yet further isotopic diversity might be introduced, at least in the palatial Bronze Age, by consumption at Knossos of animals reared elsewhere: for example, slightly higher or lower  $\delta^{13}\text{C}$  values in animals reared mainly in the drier east or wetter west of Crete, respectively.

Of the forage categories modelled in Fig. S1, lowland rough browse was probably available year-round, but lowland rough graze relatively scarce in summer, upland rough graze normally inaccessible in winter, and pannage limited to a few autumn-winter months.  $\text{C}_4$ -rich coastal rough pasture too was traditionally exploited mainly in winter, while seasonal availability of pasture on cultivated land depended on rotation and fallowing regimes. To varying degrees, therefore, most livestock probably exploited mixtures of pastures, rather than any single modelled category, but the range of potential combinations is too large, and the underpinning data currently too coarse, to warrant formal dietary mixing models.

Textual references to fattened or finished FP livestock may also imply consumption of isotopically enriched fodder, if this included  $\text{C}_4$  millet or tiger nut (with very high  $\delta^{13}\text{C}$  values) or  $\text{C}_3$  grain (with slightly higher  $\delta^{13}\text{C}$  and perhaps  $\delta^{15}\text{N}$  than corresponding straw/chaff fodder and stubble/fallow pasture). Neolithic use of  $\text{C}_3$  grain fodder has also been discussed in relation to livestock dental microwear (Mainland & Halstead 2005) and both macroscopic (Valamoti & Charles 2005) and isotopic (Vaiglova *et al.* 2014a) archaeobotanical data from Greece, but the bone collagen data presented below reflect long-term average diet and should be insensitive to

fattening immediately before slaughter. If some livestock were reared intensively, however, fed significant quantities of grain like recent household goats, sheep and especially pigs, their bone collagen might exhibit raised  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values.

## MATERIALS AND METHODS

We analysed carbonized cereal grains and pulse seeds from 34 samples from John Evans' 1969-70 Neolithic excavations, currently under final study by Sarpaki. Nitsch *et al.* (2019) have previously presented  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for four additional IN samples, including free-threshing wheat grain directly AMS-dated to the early 7th millennium cal BCE (Douka *et al.* 2017) from Evans' 1960 excavations (Evans 1968, 269), and for FP crops in Storeroom P of the Unexplored Mansion (Jones 1984; Popham 1984). Results of both new and previous analyses are presented in detail in Table S1 and in summary form in Table 2.

Samples of *c.* 5 to 10 grains were homogenized in an agate mortar and pestle. Pre-screening for contamination from the burial environment, using Fourier transform infrared spectroscopy (FTIR) as in Vaiglova *et al.* (2014b), detected no contamination so samples were not pre-treated. Plant data reliability was assessed by comparing  $\delta^{15}\text{N}$  values to C:N ratios (Fig. S2; Supplementary text S3) and reported values from other sites in the region.

650 faunal samples identifiable to species were selected for analysis from all phases of prehistoric occupation (Table S2a-b). Because faunal material has been recovered in much larger quantities than plant remains, samples from the lengthy Late Neolithic are analysed below for two separate phases, LNI and LNII (Table 1), but separate analysis of different FN subphases awaits completion of ongoing chronological work (Tomkins 2007; 2020). Due to the taxonomic composition of the assemblage, chronological coverage is good for sheep, patchier for goats, pigs and especially cattle, restricted to the later Bronze Age for fallow deer, and sparse for dog, badger and especially horse (one specimen). Selection of specimens, where possible from a single anatomical zone (distal humerus), sought to minimise any effects of intra-skeletal variability (Rodière *et al.* 1996, 181) and the risks of taking multiple samples from one individual or of sampling animals young enough to have been suckling at/shortly before death (and thus yielding elevated  $\delta^{15}\text{N}$  values – Balasse & Tresset 2002). A few mandibles with teeth were also sampled, including some previously subjected to multi-isotope sequential analysis of

enamel to explore the relationship of diet ( $\delta^{13}\text{C}$ ) to seasonal vertical ( $\delta^{18}\text{O}$ ) and lifetime horizontal ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) movement of FP sheep and goats (Isaakidou *et al.* 2019). For details of sampling protocol, laboratory and quality control procedures, see Supplementary text S4.

## RESULTS AND DISCUSSION: PLANT REMAINS

The results from stable isotope analysis of carbonised grains are detailed in Table S1, while summary  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  data are presented by broad crop type (cereals, pulses) and chronological period (Neolithic, Bronze Age) in Table 2 and displayed by crop taxon and chronological phase (IN, LN (including 13 cereal and two pulse samples of LN I and one pulse sample of LN II date), FN, FP) in Fig. 4. The standard deviations for  $\delta^{13}\text{C}$  (cereals  $\pm 0.7\%$ , pulses  $\pm 0.9\%$ ) and  $\delta^{15}\text{N}$  (cereals  $\pm 1.3\%$ , pulses  $\pm 1.0\%$ ) values suggest that the samples overall represent a range of growing conditions (cf. Nitsch *et al.* 2015, 11 table 5), as do those of Neolithic cereals and pulses and, in part, Bronze Age cereals ( $\delta^{15}\text{N}$  only) and pulses ( $\delta^{13}\text{C}$  only). ANOVA and Welch two-sample t-test analysis (Table 3) highlights significant differences between broad crop types and chronological periods, especially in  $\delta^{13}\text{C}$ , and between some crop taxa and chronological phases.

Variability in growing conditions might in principle reflect climate/weather or husbandry practices. While pulse  $\delta^{13}\text{C}$  values are lower in the Neolithic than the Bronze Age, however, and thus consistent with suggestions of long-term aridification, those for cereals exhibit the opposite tendency (Table 2, Fig. 4). This suggests that any effects of such climate change (cf. Riehl *et al.* 2014) are overridden by differences in husbandry, both diachronically and between pulses and cereals.

In terms of  $\delta^{13}\text{C}$  values, Fig. 4 shows a striking contrast between the Neolithic and FP samples in the relative position of cereals and pulses: whereas pulses (mostly lentil) tend to be *similar to or lower than* the predominant cereal (free-threshing wheat) through the Neolithic, FP pulses are mostly *higher* than the associated cereals. Fig. 5 expresses the Knossos stable carbon isotope values in terms of  $\Delta^{13}\text{C}$ , enabling comparison with modern baselines for poorly to well-watered cereals and pulses. Neolithic pulses all fall into the ‘well-watered’ band, as do most samples of the predominant Neolithic cereal, free-threshing wheat, while a few of the latter and almost all barley samples are moderately watered. By contrast, the FP cereals (emmer and barley) are mostly ‘well-watered’, while the associated pulses (winged vetchling and Celtic bean) are

variously moderately or well-watered. These results suggest that the Neolithic free-threshing wheat and pulses grew under similar conditions as regards water availability, and so were potentially rotated or inter-cropped on the same plots, a possibility further explored below in terms of nitrogen. The apparently drier growing conditions of Neolithic barley are potentially due to sowing, as was usual in recent pre-mechanised agriculture in Greece, later in the rotation cycle than wheat and thus with greater competition for moisture from weeds. Of the FP crops stored in the Unexplored Mansion, however, pulses and barley apparently experienced quite variable water availability and so cannot have been grown on the same plots of land as, and in rotation with, the strikingly well-watered emmer wheat (Nitsch *et al.* 2019).

Fig. 6 also reveals diachronic variation in  $\delta^{15}\text{N}$  values, which are generally higher for cereals and pulses in the IN, lower in the LN and then again higher in the FN and lower in the FP. Manuring of cereals is plausible at moderate levels throughout the Neolithic sequence, while for pulses the elevation of many  $\delta^{15}\text{N}$  values well above 0‰, the value of atmospheric  $\text{N}_2$ , suggests manuring heavy enough to inhibit their fixation of nitrogen from this source. Manuring was perhaps particularly intensive when the community was very small during the IN (when one emmer sample with a strikingly low  $\delta^{15}\text{N}$  value of 1.7‰ was potentially grown on a fertile newly cleared plot, manuring of which would have been counter-productive – Halstead 2018) and decreased with expanding community size during the later Neolithic. In the recent past, intensive manuring was often limited, even with animal traction, to within *c.* 500 m of the settlement (Halstead 2014, 217) and this threshold was perhaps reached (see Isaakidou 2008, 103 table 6.2) during LN II or FN if the population of Knossos approached not 250 or less but 400-500 head (Table 1). If so, the subsequent FN recovery in cereal  $\delta^{15}\text{N}$  values might reflect greater use of draught cattle to promote intensive gardening, given the increase through the Neolithic in the relative abundance of cattle and the severity of traction-related skeletal remodelling/pathologies (cf. Isaakidou 2006; 2008; 2011). Either way,  $\delta^{15}\text{N}$  values of LN and FP cereals and pulses suggest relatively light manuring that is consistent, for the latter phase, with the extensive agriculture anticipated on the basis of urban growth at Knossos and of Linear B textual evidence for grain production.

## RESULTS AND DISCUSSION: FAUNAL REMAINS

The results from stable-isotope analysis of faunal samples are detailed in Table S2a-b. Of 645 faunal samples, 71% yielded usable results. Failure rates decline from Neolithic (42%) to Bronze Age (14%) and through successive Bronze Age phases (Table S4), inviting attribution to length of burial. Failures are particularly high in cattle, however, identifying significant observed differences between species in culinary (Isaakidou 2005, 196-203; 2007) and discard treatment (Isaakidou 2008, 95 fig. 6.2) as possible contributory factors (eg, depletion of bone collagen by prolonged boiling of intensively fractured cattle bones – cf. Roberts *et al.* 2002).

Table 4 presents summary statistics and Fig. S3 scatter plots of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  results by phase for all species, while Fig. 7 displays these data as box-and-whisker plots (with outliers representing values exceeding interquartile range  $\times 1.5$  for each phase) for sheep (Fig. 7a-b), goat (Fig. 7c-d), cattle (Fig. 7e-f) and pig (Fig. 7g-h). Table 5 shows significant ( $p < 0.05$ ) differences (ANOVA with Tukey's post-hoc tests) in  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values between phases for both sheep and goat (the two largest samples) and between goat and other common livestock species for individual phases.

We first consider the possible impact of long-term aridification or late-seventh (EN), late-fifth (FN) and late-third (LPreP) millennia BCE cooler, drier episodes. Aridification should raise  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values, but no consistent long-term trend is evident:  $\delta^{13}\text{C}$  values rise in goats, but only slightly in sheep, and fluctuate in pigs;  $\delta^{15}\text{N}$  values fluctuate in sheep and pigs and decline in goats; data for cattle are few and uninformative (Fig. 7). Nor are expected dry episodes mirrored in short-term peaks in  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  values. For sheep, offering the most continuous diachronic dataset, mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values are strikingly low in OP, but not unusually high in EN, FN or LPreP. For goat, the highest  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  outliers date to climatically 'normal' FP and PreP, respectively; and, while the second highest  $\delta^{13}\text{C}$  outlier (-16.8‰) from a FNIB deposit *might* date to a late 5<sup>th</sup> millennium BCE (Tomkins 2020, 56, fig. 2) dry episode, the same excavation context yielded four other goat specimens with values (-20.2 to -19.7‰) close to the Neolithic (-20.0‰) and Bronze Age (-19.8‰) means. Husbandry thus apparently overrides climate change in shaping observed variability in livestock stable isotope values, as also in crop  $\delta^{13}\text{C}$  values (above). Likewise, since diachronic trends in  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values differ between sheep, goats and pigs, husbandry practices evidently override any effects of physiological differences between species in shaping livestock stable isotope values.

Excluding the phase-by-phase outliers defined for sheep, goat and cattle (Fig. 7), which are discussed in Supplementary text 5, we next compare the bone collagen data to modelled  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for Neolithic and Bronze Age forage categories to explore the dietary, and thus – indirectly – husbandry patterns, of each animal species consumed at Knossos. Modelled values for forage derived from cultivated land are based on measured values for ancient Knossian grain, while those for forage from uncultivated land are based on comparative east Mediterranean data assuming mean annual rainfall at Knossos of ~500mm. In comparing modelled forage values with bone collagen data, we assume trophic-level shifts between plant diet and animal tissue in herbivores and pigs of 5‰ for  $\delta^{13}\text{C}$  and 4‰ for  $\delta^{15}\text{N}$  (Supplementary text S2). The resulting dietary reconstructions are plausible in terms of livestock feeding preferences and Knossos' changing size and regional status. The adoption of different values for mean rainfall (~600 mm) and for trophic-level shifts ( $\delta^{13}\text{C}$  – 4‰ or 6‰;  $\delta^{15}\text{N}$  – 3‰ or 5‰) yields dietary reconstructions either broadly similar or less compatible with livestock feeding preferences and other known constraints (see Supplementary text S6).

### *Sheep*

For sheep, the most abundant animal at Knossos, the range of  $\delta^{13}\text{C}$  values broadens over time, implying long-term dietary diversification, while  $\delta^{15}\text{N}$  values exhibit IN-LN I and LN II-OP cycles of decline interrupted by LN II and NP recovery (Fig. 7a-b, Table 4). Fig. 8 displays these results, adjusting bone collagen values for trophic level shifts of ~5‰ in  $\delta^{13}\text{C}$  and ~4‰ in  $\delta^{15}\text{N}$ , as 95% confidence ellipses overlain on modelled ellipses for different forage categories at 500 mm rainfall.

For Neolithic sheep (Fig. 8a),  $\delta^{13}\text{C}_{\text{diet}}$  indicates consumption overwhelmingly of  $\text{C}_3$  plants, as expected, and best matches the modelled ranges for  $\text{C}_3$  forage from cultivated land and, more marginally, lowland rough pasture. Of the former,  $\text{C}_3$  grain was apparently not of major importance, while small ruminants like sheep are ill suited to a coarse diet of cereal straw/chaff. Sheep, under traditional Mediterranean management, only consumed cereal straw/chaff if supplemented by higher-quality grain, hay or pulse straw, but were widely and closely associated with stubble/fallow and, less so, young cereal pasture. Sheep  $\delta^{15}\text{N}_{\text{diet}}$  values largely overlap the modelled range for fallow/stubble pasture, indicating the close association of Neolithic sheep with more (especially in IN and LN II, with high  $\delta^{15}\text{N}_{\text{diet}}$  values) or less well-manured, cultivated

land, but also extend into the range for lowland rough graze. In practice, most sheep probably exploited a mixture of cultivated and rough graze, given their partly complementary seasonal availability.

Bronze Age sheep likewise consumed a predominantly C<sub>3</sub> plant diet, including both forage from cultivated land and rough graze (Fig. 8b). Of the former, their  $\delta^{13}\text{C}_{\text{diet}}$  overlaps most with nutritionally improbable straw/chaff, moderately with grain, and least with stubble/fallow graze, but the modelled range for stubble/fallow may be misleadingly narrow and low due to derivation exclusively from analyses of cereal grain in the FP ‘Unexplored Mansion’ destruction horizon. Cereals and pulses from this complex were not grown in rotation on the same land (above), so the relatively well-watered cereals represent only part of the range of FP growing conditions. Accordingly, fallow/stubble pasture was probably again the primary contribution of cultivated land to Bronze Age sheep diet. Lower  $\delta^{15}\text{N}_{\text{diet}}$  values than in the earlier Neolithic should partly reflect lighter manuring of cultivated land as a corollary of more extensive Bronze Age agriculture, but also suggest heavier use of rough pasture – primarily lowland C<sub>3</sub> rough graze, judging by  $\delta^{13}\text{C}_{\text{diet}}$  values.

Sheep consumed at Neolithic-Bronze Age Knossos were thus closely associated throughout with stubble/fallow pasture on cultivated land, with some use also of lowland rough graze. Over time, stubble/fallow-grazing included more lightly manured land (mirroring more extensive cultivation) and use of C<sub>3</sub> rough graze expanded (mainly in the lowlands, but also – as indicated by incremental dental data – seasonally in the uplands). These changes in pasture use arguably reflect an increasing scale of herding.

### *Goat*

For goat, less abundant than sheep throughout the Knossos sequence, the stable isotope data again reveal a broadening of diet from Neolithic to Bronze Age, but in  $\delta^{15}\text{N}$  rather than  $\delta^{13}\text{C}$  values (Table 4; Fig. 7c-d). Thus, while the two species share very similar IN-EN  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values, they differ significantly in  $\delta^{13}\text{C}$  values in most phases from the later Neolithic onwards and also in  $\delta^{15}\text{N}$  during the NP (Table 5). This progressive dietary divergence of sheep and goat (Fig. 9a-b) matches expectations that growing livestock numbers would favour their separate herding.

Again allowing for trophic-level shifts ( $\delta^{13}\text{C} \sim 5\text{‰}$ ,  $\delta^{15}\text{N} \sim 4\text{‰}$ ), Neolithic goats share with sheep a comparable range of  $\delta^{15}\text{N}_{\text{diet}}$  values (Fig. 8a), suggesting a similar association (especially in the earlier Neolithic – Fig. S3) with stubble/fallow pasture on well manured cultivated plots, but their somewhat higher  $\delta^{13}\text{C}_{\text{diet}}$  values (increasingly through the later Neolithic – Fig. S3) imply intake also of browse – possibly from shrubs/trees on boundaries between cultivated plots. In mixed herds on hedged stubble fields in Greece today, while sheep graze weeds and unharvested cereal ears, goats also browse peripheral bushes and brambles (Yiakoulaki & Papanastasis 2005). Bronze Age goats (Fig. 8b) substantially overlap with sheep and with forage on cultivated land, especially in the pre-palatial phases (Fig. S3), but from LPreP onwards increasingly combine raised  $\delta^{13}\text{C}_{\text{diet}}$  with low  $\delta^{15}\text{N}_{\text{diet}}$  values that suggest heavy use of rough browse or possibly upland summer graze; goat feeding preferences favour browse, as do incremental dental  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  values suggesting that at least two FP goats (MUM78 and MUM70: Fig. 8b nos. 4-5) remained year-round in the lowlands (Isaakidou *et al.* 2019, 50).

While earlier Neolithic goats were maintained mainly on well manured cultivated land, later Neolithic-PreP goats apparently combined stubble/fallow grazing with browsing, but possibly on the margins of cultivated plots and so were potentially herded with sheep. From the LPreP onwards, however, while some goats still grazed arable land, most exploited rough browse and so were herded separately from sheep (Figs 8b and 9a-b).

### *Cattle*

Cattle are well represented in the faunal assemblage from MN onwards, but by very fragmented (Isaakidou 2005, table 6.12) and perhaps intensively boiled specimens and thus by sparse isotopic data. Cattle diet ostensibly broadens slightly from Neolithic to Bronze Age, with lowest and highest  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of palatial date, but Bronze Age data are more abundant than Neolithic.

With the same trophic-level adjustments, the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  ranges for both Neolithic and Bronze Age cattle essentially replicate those for sheep and so again indicate heavily  $\text{C}_3$ -dominated diet with reliance primarily on forage (stubble/fallow graze and/or straw/chaff fodder) from more or less manured, cultivated land, supplemented by some rough grazing (Fig. 8a-b). Among Bronze Age cattle (but not sheep), low  $\delta^{13}\text{C}_{\text{diet}}$  values tend to be associated with low  $\delta^{15}\text{N}_{\text{diet}}$  and high

$\delta^{13}\text{C}_{\text{diet}}$  with high  $\delta^{15}\text{N}_{\text{diet}}$  (Figs 8b and S3). The former may reflect the ability of cattle (unlike sheep) to survive on a coarse diet of straw (cf. Bell 1971), while the latter may be due to feeding of  $\text{C}_3$  grain supplements to some animals.

### *Pig*

For both Neolithic and Bronze Age pigs, modestly represented in the assemblage, the ranges of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values again largely replicate those for sheep (Fig. 7g-h). Applying the same trophic-level shifts as for sheep, goats and cattle (Fig. 8a-b), Knossos pigs consumed a diet dominated by  $\text{C}_3$  forage from more or less manured, cultivated land (especially stubble/fallow graze) and some rough graze.  $\text{C}_3$  browse (with relatively high  $\delta^{13}\text{C}_{\text{diet}}$  and low  $\delta^{15}\text{N}_{\text{diet}}$  values) and pannage (with yet higher  $\delta^{13}\text{C}_{\text{diet}}$  values) were not important, but Bronze Age pigs with higher  $\delta^{13}\text{C}_{\text{diet}}$  and also higher  $\delta^{15}\text{N}_{\text{diet}}$  values (Figs 8b and S3) had perhaps consumed waste human food or, as suggested for some Bronze Age cattle,  $\text{C}_3$  grain.

### *Horse*

A single Postpalatial equid specimen (proximal metatarsal) is of a size suggesting horse (or conceivably mule, identified at coeval mainland Tiryns – von den Driesch & Boessneck 1990) rather than donkey. Assuming trophic-level shifts of 5‰ for  $\delta^{13}\text{C}$  and 4‰ for  $\delta^{15}\text{N}$ , this animal grazed rough pasture with no hint of higher-quality fodder (Fig. 8b).

### *Dog*

Dogs are represented by low numbers of skeletal remains in all phases. Six Neolithic samples yielded narrower ranges of both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values than five Bronze Age specimens (Table 4). To explore whether canine carnivory extended beyond the scavenging for bone marrow that is indicated by gnawing marks (Isaakidou 2005), a carnivorous dog diet is modelled assuming prey-predator trophic-level shifts of 1‰ for  $\delta^{13}\text{C}$  and 4‰ for  $\delta^{15}\text{N}$  (Supplementary text S2; Fig. 10). Most of the resulting  $\delta^{13}\text{C}_{\text{diet}}$  and  $\delta^{15}\text{N}_{\text{diet}}$  values are compatible with consumption of other domestic animals, but would only indicate predominant carnivory if (improbably) Bronze Age dogs mainly ate goats (contrary to the evidence of gnawing traces, present on specimens of all species) and Neolithic dogs mainly ate animals that had grazed rough pasture and lightly manured stubble/fallow. Thus Knossian dogs, and especially the Bronze Age specimen with the

lowest  $\delta^{15}\text{N}_{\text{diet}}$  value, probably subsisted in large measure on cultivated  $\text{C}_3$  grain and perhaps mainly, as commonly in the recent past, on cereal bran with lower  $\delta^{15}\text{N}$  values than whole grain (Nitsch *et al.* 2015, table 6).

### *Badger*

Badgers are as well represented as dogs in the Neolithic, but thereafter very scarce. The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of one Neolithic and two Bronze Age specimens fall largely within the ranges for dogs, consistent with the expected omnivorous diet.

### *Fallow Deer*

Fallow deer bones occur in small numbers at palatial Knossos and, albeit possibly due to excavation bias, only in elite contexts. Seven NP samples essentially fall within the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  ranges of Knossos NP-PostP sheep, as does the single PostP specimen. Eight FP samples exhibit similar  $\delta^{15}\text{N}$  values but a broader  $\delta^{13}\text{C}$  spread across both sheep and goat ranges (Table 4). Assuming trophic-level shifts of 5‰ for  $\delta^{13}\text{C}$  and 4‰ for  $\delta^{15}\text{N}$  (Fig. 11), the NP, PostP and four ‘sheep-like’ FP specimens suggest diet dominated by stubble/fallow grazing on variably manured land, perhaps with some rough grazing, while the four ‘goat-like’ specimens fall near the interface between arable-based forage and lowland browse. European fallow deer (*Dama dama*) in temperate Europe (Jackson 1977; Putman *et al.* 1993), like Persian fallow (*Dama mesopotamica*) in the east Mediterranean (Zidon *et al.* 2017), are mixed grazers/browsers, while the former at least raid field-crops from wooded refuges (Thirgood 1995). European fallow deer on the southern Aegean island of Rhodes, however, avoid pasture and water fouled by sheep and compete more with domestic goats (Theodoridis *et al.* 2008). It is tempting, therefore, to identify the ‘sheep-like’ specimens as *enclosed* on farmland (as at Dudley Castle, England – Sykes *et al.* 2016, 121 fig. 8) and their ‘goat-like’ counterparts as free-range, whether escaped or released, and more reliant on rough browse. The suggested enclosure of this imported deer species is of considerable intrinsic importance for understanding its management on Bronze Age Crete, but is also methodologically significant in precluding use of stable isotope values for fallow deer as a proxy measure for ‘natural’ coarse pasture, free from anthropogenic inputs.

## REASSESSING KNOSSIAN LAND USE AND POLITICAL ECONOMY

### *Mixed farming: integration of crops and livestock*

Perhaps the most salient feature of the Knossos stable isotope results is the implied close interdependence of arable and pastoral farming: cultivated land was throughout the Neolithic and Bronze Age a key pasture resource for livestock, especially sheep, but also pigs, cattle and to some extent goats; and animal manure underpinned intensive crop husbandry, especially in the earlier Neolithic. The importance of manure to early crop husbandry raises questions regarding its attendant risks, distribution and availability. First, recent Cretan farmers spread manure very sparingly, from fear of crops ‘burning’ in drought years (Halstead 2014, 213-15), but a generally moister Bronze Age and, especially, Neolithic climate would have mitigated this risk. Secondly, draught cattle could have eased distribution of any stall-manure and human night-soil accumulated at the settlement (Isaakidou 2008), but mild winters and lack of predators (other than stray dogs, large raptors and other humans) would have limited need for stalling, while delivery of dung (and urine) directly by grazing or penned livestock would have saved human labour in muck-spreading (Halstead & Isaakidou 2020). Thirdly, availability of manure depends on the scale and form of animal husbandry. Early livestock, if closely tied to small cultivated plots, would have been few in number: a family of say 4-5 head sowing only 1-2 ha of grain crops (Halstead & Isaakidou 2020, 91-2) might maintain at most 1-2 sheep solely on stubble/fallow pasture (at 1/ha– Le Houerou 1977, 259). Penning these animals overnight on such plots (in addition to grazing stubble, fallow and, in lean seasons, rough pasture) would have made maximum use of available manure (Halstead & Isaakidou 2020) and, thanks to deposition of both urine and faeces, may have enhanced crop  $\delta^{15}\text{N}$  values more than would dry stall manure (cf. Abell *et al.* 2019), but seems unlikely to have maintained the fertility levels implied by crop  $\delta^{15}\text{N}$  values (Halstead & Isaakidou 2020, 91-2). Alternatively, a family with access to working cows that sowed say twice the area of grain crops normally needed (cf. Halstead 1989) and allowed livestock to graze any growing crops that failed due to drought or weeds or lodging (stem collapse – a particular risk with heavy manuring), or were surplus to human needs, might have supported 5-10 sheep or more (cf. Le Houerou 1977, 263 table 3). Penning of animals on sown cereal pasture entails radically closer integration of early crop and livestock husbandry than is usually envisaged, but would account better than more familiar husbandry regimes for the high  $\delta^{15}\text{N}$  values of earlier Neolithic Knossos cereals and pulses (Halstead & Isaakidou 2020).

After the earlier Neolithic, there are indications of more extensive crop husbandry and of livestock management on more distant and varied pasture that extended to lightly manured arable land, rough graze (including transfer of some palatial-era sheep to uplands in summer) and, for Bronze Age goats, arboreal browse. Use of distant rough pasture would have facilitated the escape of adventurous livestock and formation of feral populations, suspected from the later Neolithic onwards on biometric grounds (Isaakidou 2005), but stable isotope data as yet neither support nor refute this scenario.

#### *Land use in socio-political context*

Other things being equal, a likely corollary of the growth of Knossos and associated expansion of crop husbandry was increasingly unequal access to good-quality, nearby land suitable for intensive cultivation, while access to draught cattle for tillage and transport would also have become more critical (Isaakidou 2008). On the other hand, communal rather than household-level production and consumption of food, as proposed by Tomkins (2004) for the earlier Neolithic, might initially have countered any such tendency.  $\delta^{15}\text{N}$  values for IN cereals are quite variable, but might reflect the time elapsed since, rather than intensity of, manuring. For IN-MN sheep, however, although the narrow  $\delta^{13}\text{C}$  range is compatible with shared grazing on relatively uniform pasture, variable  $\delta^{15}\text{N}$  values imply these animals were not herded together across the community's stubble, fallow and perhaps sown plots, but were confined in small numbers on particular plots or holdings with contrasting manuring histories. Both livestock and cultivation plots, therefore, from early in the settlement's life, were apparently managed not collectively but by small ('household') units. Moreover, on this scenario, the broad crop  $\delta^{15}\text{N}$  range probably does reflect manuring of variable intensity and thus differences between earlier Neolithic households in livestock numbers and also in area sown and the potential for surplus grain production. In turn, a differential capacity to provide 'surplus' grain to needy neighbours or meat for commensal occasions is likely to have underpinned competitive dynamics within Neolithic society (Halstead 1989; Isaakidou 2008, 105-7).

Thereafter, values for  $\delta^{13}\text{C}$  (from MN) and  $\delta^{15}\text{N}$  (from LN II) progressively diverge between sheep and goats (Fig. 9a-b), implying use of increasingly different and thus distant pasture, and hence active herding of the two species independently of each other, such that the increasing proportion of goats relative to sheep from the later Neolithic onwards (Isaakidou 2008, 95 fig.

6.2) arguably represents an absolute as well as relative expansion of goat numbers. Herding labour may accordingly have displaced pasture as the limiting factor on livestock numbers, while large excavated houses at later Neolithic Knossos, if accommodating extended households (Isaakidou 2005, 64), could better have mobilised additional labour for larger and more mobile herds (cf. Halstead 2014, 292-4).

While crop and livestock stable isotope values document increasingly extensive husbandry over the early 7<sup>th</sup>-late 2<sup>nd</sup> millennia BCE, consistent with expectations from the expanding size and regional sway of Knossos, the pace of demographic and political change was uneven and the same might be expected of land use. Indeed, cereal  $\delta^{15}\text{N}$  values are higher in IN (5.5-7.3‰, mean 6.3‰; excluding the low outlier discussed above) and FN (4.5-8.4‰, mean 6.0‰) than intervening LN I (2.6-5.2‰, mean 4.1‰). Cereal  $\delta^{15}\text{N}$  values are not currently available for other phases of the Neolithic, but those for sheep, closely linked to arable land and thus plausible proxies for cereal growing conditions, decline from IN to LN I, before increasing in LN II-FN (Fig. 7b). The low LN I  $\delta^{15}\text{N}$  values for cereals and sheep coincide with expansion of the settlement and thus its cultivated radius, apparently resulting in less intensive crop husbandry that was subsequently reversed, perhaps by FN cessation of growth (Table 1) and/or increasing LN-FN frequencies of cattle (Isaakidou 2008), some bearing stress markers consistent with draught use (Isaakidou 2006). Bronze Age crop stable isotope data are limited to the elite FP ‘Unexplored Mansion’, but sheep  $\delta^{15}\text{N}$  values again offer a proxy for cereal growing conditions with a renewed cycle of decreasing values from LN II-FN to OP and then NP-FP increase. OP Knossos was one of at least three palatial towns in central Crete, but FP and perhaps NP Knossos had subsumed its largest ‘rival’ at Phaistos to the south, probably also that at Malia to the east, and many smaller centres (Bennet 1985; 2012, 239-41). A plausible reading of sheep  $\delta^{15}\text{N}$  values, therefore, is that rapid urban growth at OP Knossos was supported by extensive cultivation at increasing distance, but NP-FP Knossos relied more on mobilising grain and livestock raised on subordinate centres’ core rather than marginal land (as argued from FP texts for grain and sheep – Bennet 1985; Halstead 1981b).

The FP texts do not document provisioning of the ruling elite itself (cf. Lane 2004, for the mainland palace at Pylos), who presumably consumed produce from their own gardens, fields and herds, of which the first may have occupied open spaces between urban elite buildings

(Shaw 1993, 680) and the second appear in FP texts (Zurbach 2005, 325-8). The ‘Unexplored Mansion’ pulses, judging by their elevated  $\delta^{15}\text{N}$  values, were indeed products of intensive gardens, while the cereals were grown in well-watered conditions and so probably on good land (possibly after bare fallow to eradicate weedy competitors for moisture), perhaps equivalent to that at the FP subordinate centres from which ‘wheat’ was centrally mobilised. Lastly, if fallow deer consumed at Knossos were initially penned, as stable isotope results suggest, this would have facilitated socially restricted exploitation, consistent with their recurrence in both Cretan and mainland elite art (Palmer 2012) and reinforcing the argument that diacritical cuisine helped legitimise the palatial elite (Isaakidou 2007).

### *Knossos in Aegean context*

Carbon and nitrogen stable isotope values for Knossos cereals and pulses largely fall within the ranges previously reported for Neolithic and Bronze sites on the Greek mainland (Figs 12-13; Vaiglova *et al.* 2014a; 2020; 2021; Styring *et al.* 2015; Nitsch *et al.* 2017), reflecting similarity in the relatively small-scale arable landscapes that early farmers created (cf. Bogaard 2005), despite regional differences in climate. Livestock display greater inter-site isotopic differences (Table S6; Fig. 14a-b), reflecting use of regionally variable pasture resources beyond (and in addition to) arable land. Most strikingly, central and north Greek cattle at EN-LN Halai (Vaiglova *et al.* 2021, 11 fig. 3), LN Makriyalos (Vaiglova *et al.* 2018, 13 table 3), late EBA-LBA Archontiko and LBA Toumba Thessalonikis (Nitsch *et al.* 2017, tables S6-S7) exhibit some high  $\delta^{13}\text{C}$  values attributable to grazing on saline coastal pasture. Conversely, in the absence of such pasture, cattle at MN-LN Kouphovouno (Vaiglova *et al.* 2014a, 209 table 2) and LBA Mycenae (Price *et al.* 2017, 121-2 tables 1-2) on the southern mainland and at Neolithic-Bronze Age Knossos exhibit  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values close to those of sheep and probably grazed on cultivated land.

Indeed, despite the very large scale of herding in central Crete, at least in the textually rich FP phase, the isotopic ranges of the common livestock species differ much less at Knossos (with significant differences only between LN goats and the other three species and only from the later Neolithic onwards – Table 5) than at Neolithic Halai, Kouphovouno and Makriyalos or Bronze Age Archontiko and Toumba (Fig. 14a-b), consistent with the importance of cultivated land (implied by relatively high  $\delta^{15}\text{N}$  values) to Knossos sheep, cattle and pigs and even, in part,

goats. At LBA Mycenae, also a major southern Greek palatial centre, the ranges for all four common domesticates, including goats, are compatible with forage predominantly from cultivated land. Also, while  $\delta^{15}\text{N}$  values of Neolithic Knossos livestock are generally higher than those for Kouphovouno and Makriyalos (but not Halai), Bronze Age values for sheep, goats and pigs, and likewise for sheep and goats from LBA Mycenae, are lower than those for Archontiko and Toumba, consistent with extensive agriculture, and thus lightly/un-manured stubble/fallow pasture, of larger scale on Crete and the southern mainland than in northern Greece, where the urban settlements and complex hierarchies of the later Bronze Age southern Aegean were lacking (Andreou 2010).

## CONCLUSIONS

Large-scale stable isotope analysis of the exceptional archaeobotanical and faunal archive from early 7<sup>th</sup>-late 2<sup>nd</sup> millennium BCE Knossos has yielded significant insights at several levels. First, despite both long- and short-term climatic changes, any impact thereof on crops or livestock was not detectable isotopically and was overwritten by variation in husbandry (and, doubtless, between good and bad years), underlining the dangers (also Manning 2017) of inferring catastrophic local agricultural failures from transregional proxy climate records.

Secondly, in demonstrating the intensive nature of initial grain growing, the close integration therewith of livestock rearing, and the subsequent expansion through the later Neolithic and especially later Bronze Age of extensive agriculture and large-scale herding, it has provided empirical confirmation of land use models previously advanced on largely circumstantial grounds. It likewise confirms the tendency, with expanding scale of husbandry, for differential treatment of cereals and pulses and divergent pasturing especially of goats from sheep, cattle and pigs. Sheep, however, apparently maintained a close association throughout with pasture on cultivated land and so offer a useful proxy for crop growing conditions, for which direct stable-isotope data are temporally patchy and, in the palatial era, socially selective.

Moreover, a radically unexpected outcome of the apparently close integration of *all* earlier Neolithic livestock with the cultivated landscape is that apparently generous manuring of grain crops was arguably achieved only by running livestock not only on stubble/fallow plots, but also on crops sown to be harvested for grain or grazed *in situ* as circumstances dictated. In the longer

term, the close association of Neolithic-Bronze Age sheep (the commonest species), but also cattle and pigs, with pasture on cultivated land implies that the number of livestock per head of human population was modest and average human levels of meat consumption consequently low, although this does not rule out a more privileged diet for elite groups or indeed for the inhabitants of Knossos in general. A more direct assessment of human diet, by stable-isotope analysis of human remains, has not been attempted because dependable interpretation of results would require comparative data for coeval and contextually representative archaeobotanical and faunal samples (as, for later Bronze Age northern Greece, by Nitsch *et al.* 2017) and no occupation phase at Knossos has yet yielded adequate samples of all three classes of bioarchaeological remains.

Thirdly, although incomplete contextual information as yet precludes meaningful spatial analysis of the archaeobotanical and faunal data, the more secure and nuanced picture of changing land use achieved for Knossos offers significant insights into the community's social fabric: for example, implied household-scale management of arable and pastoral farming from the inception of the Neolithic settlement; increasing demands on human labour from perhaps the later Neolithic onwards for herding larger livestock numbers over greater distances and on more diverse pasture; the apparent transition from relatively self-sufficient OP Knossos, maintained by often extensive and probably distant farming of its own territory, to NP-FP Knossos, mobilising produce from previously competing and now subordinate centres; the role of introduced fallow deer in elite diacritical cuisine reinforced by probable NP-FP penning; and provisioning of the FP Knossian elite from (private?) intensive gardens and high-quality fields independent of the centrally administered extensive agriculture recorded in FP texts.

Lastly, it should be emphasised that, while presenting *new* and highly informative stable isotope results, we have drawn heavily on excavation and survey evidence for the history of Knossos and its region, on written (especially Linear B) records of crop and livestock management, on previous macroscopic study of archaeobotanical and faunal remains, and on ethnographically based models of past husbandry regimes and land use. Each of these strands has played a vital part in advancing understanding of Knossian land use and political economy.

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## **SUPPLEMENTARY TEXTS (separate file)**

- S1. Interpretation of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  $\text{C}_3$  grain crops in relation to changing land use
- S2. Interpretation of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of animal bone collagen in relation to changing land use
- S3. Laboratory analytical methods and quality criteria: plant remains
- S4. Sampling protocol, laboratory analytical methods and quality criteria: faunal remains
- S5. Animal bone collagen results: phase-by-phase outliers
- S6. Evaluation of assumptions underpinning modelling of livestock diet

## FIGURE CAPTIONS

Fig. 1. Map of Greece showing location of Knossos and other sites mentioned in the text

1 Knossos, 2 Agia Triada & Phaistos, 3 Trypiti, 4 Schinokapsala, 5 Petras-Kefala, 6 Priniatikos Pyrgos, 7 Malia, 8 Kouphovouno, 9 Pylos, 10 Mycenae, 11 Halai, 12 Makriyalos, 13 Archontiko, 14 Toumba Thessalonikis

Fig. 2. Plan of Knossos showing excavation sectors that provided seed and animal bone samples for the stable isotope analysis reported below (adapted from Hood & Smyth 1981)

1 Minoan Unexplored Mansion (MUM), 2 Royal Road (RR), 3 West Court House (WCH), 4 Central Court (CC), 5 Road Trials (RT), 6 Early Houses 93 (EH93), 7 Aqueduct Well (AW), 8 Hogarth's Houses (HH)

Fig. 3. Palatial political economy: a) a large gang of winnowers depicted on the 'Harvester Vase' from NP Agia Triada, Crete (photograph courtesy of Archaeological Museum of Heraklion; copyright Hellenic Ministry of Culture and Sports – Archaeological Resources Fund (TAPA)); b) palace storeroom (West Magazines) at Knossos during excavation (photograph by Ms A.M. Lloyd in 1901-04; BSA SPHS 01/2077/2566, BSA SPHS Image Collection; reproduced with permission of the British School at Athens); c) Linear B tablet De 1648 from Knossos recording (left half of tablet) two personal names and the toponym *ku-ta-to*, with which are associated (upper right) 58 male and 2 female sheep and (lower right) 40 'missing' male sheep (horizontal strokes = 10s, vertical strokes = units; drawn after photograph at <https://collections.ashmolean.org/object/476201>)

Fig. 4.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for Knossos cereal and pulse crops by phase

Fig. 5.  $\Delta^{13}\text{C}$  values for Knossos cereal and pulse crops by phase compared with modern reference bands (separated by dashed horizontal lines) representing 'well-watered' (uppermost), 'moderately-watered' (intermediate) and 'poorly-watered' (lowermost) growing conditions (Wallace *et al.* 2013); reference lines for barley assume a mixture of two- and six-row varieties

Fig. 6.  $\delta^{15}\text{N}$  values for Knossos cereal and pulse crops by phase

Fig. 7. Boxplots of Knossos bone collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values by phase for a-b) sheep, c-d) goat, e-f) cattle and g-h) pig

Fig. 8.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values (95% confidence ellipses, excluding phase-by-phase outliers) of domestic animal species, compared with modelled forage categories (after Fig. S1) for a) Neolithic and b) Bronze Age Knossos; bone collagen values adjusted for trophic level shifts of  $\sim 5\text{‰}$  in  $\delta^{13}\text{C}$  and  $\sim 4\text{‰}$  in  $\delta^{15}\text{N}$  values; numbers in Fig. 8b denote FP mandibular specimens of sheep (1-3) and goat (4-6) discussed in the text

Fig. 9. a)  $\delta^{13}\text{C}$  and b)  $\delta^{15}\text{N}$  values by phase for Knossos sheep and goat

Fig. 10.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for dog (filled circles) compared with 95% confidence ellipses for sheep, goat, cattle and pig at a) Neolithic and b) Bronze Age Knossos; bone collagen values for dog adjusted for potential carnivorous trophic level shifts of  $\sim 1\text{‰}$  in  $\delta^{13}\text{C}$  and  $\sim 4\text{‰}$  in  $\delta^{15}\text{N}$  values

Fig. 11.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values by phase for Knossos fallow deer compared with 95% confidence ellipses for Bronze Age Knossos sheep and goat and with modelled forage categories (after Fig. 8b); bone collagen values adjusted for trophic level shifts of  $\sim 5\text{‰}$  in  $\delta^{13}\text{C}$  and  $\sim 4\text{‰}$  in  $\delta^{15}\text{N}$  values

Fig. 12.  $\Delta^{13}\text{C}$  values for Knossos cereals and pulses by phase compared with those for other Neolithic and Bronze Age sites in Greece; dashed horizontal lines separate modern reference bands representing ‘well-watered’ (uppermost), ‘moderately-watered’ (intermediate) and ‘poorly-watered’ (lowermost) growing conditions (Wallace *et al.* 2013); reference lines for barley assume a mixture of two- and six-row varieties

Fig. 13.  $\delta^{15}\text{N}$  values for Knossos cereals and pulses by phase compared with those for other Neolithic and Bronze Age sites in Greece

Fig. 14. Bone collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  mean values and standard deviations ( $\pm 1 \sigma$ ) for Knossos sheep, goats, cattle and pigs compared with other sites in Greece: a) Neolithic and b) Bronze Age

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**Figure 1**

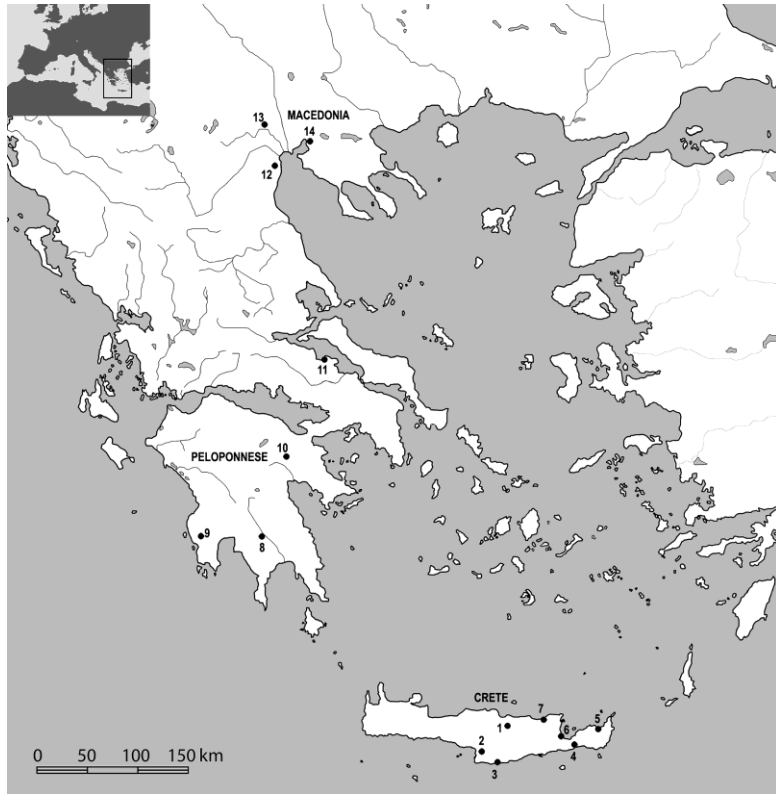


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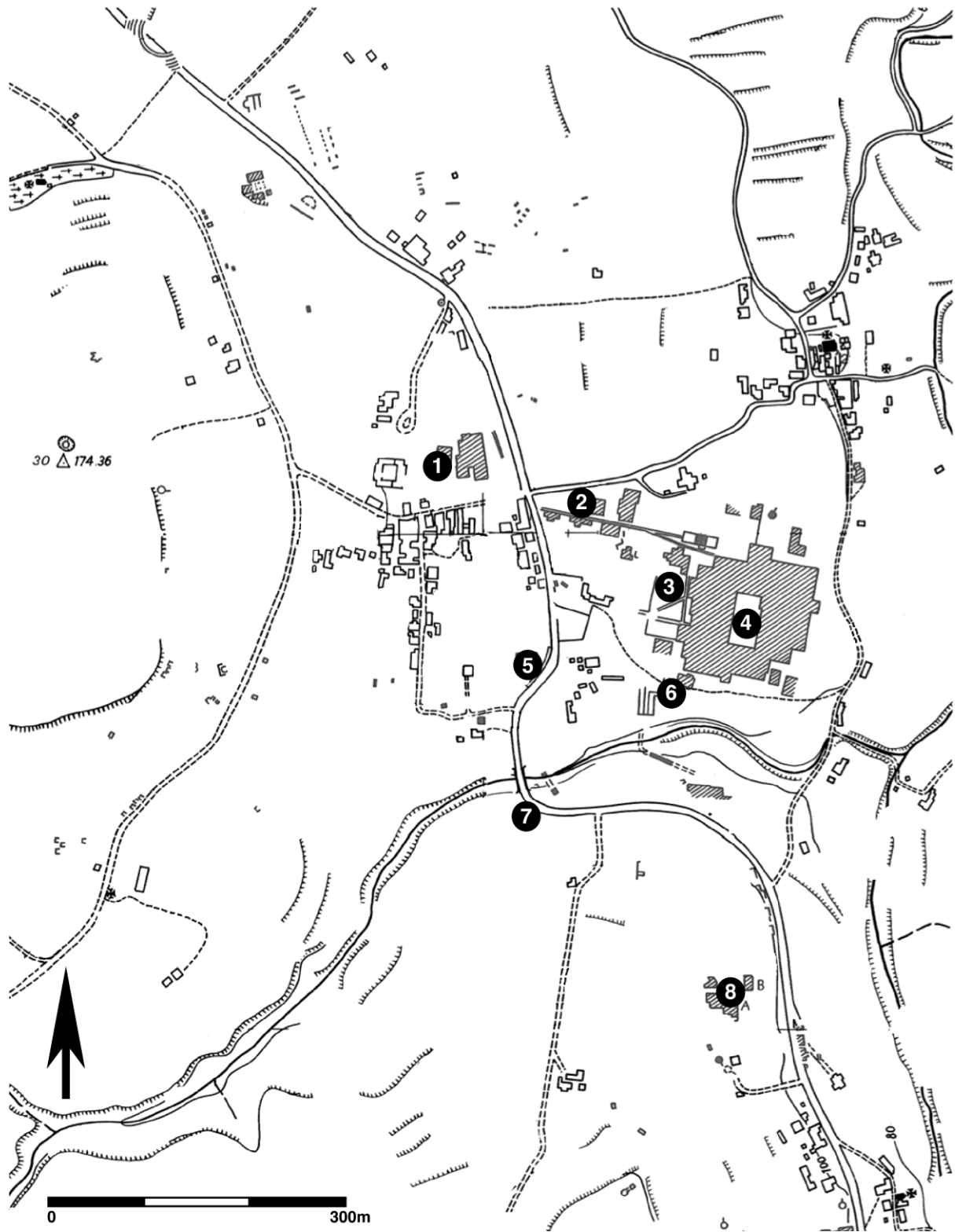


Figure 3

a.



b.



c.

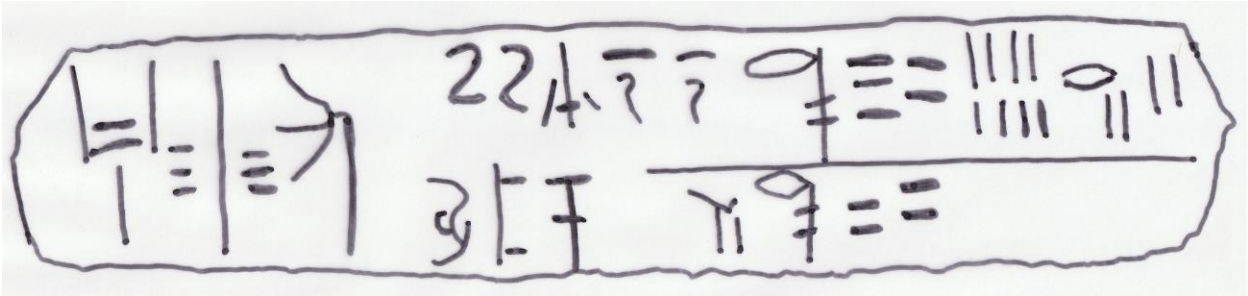


Figure 4

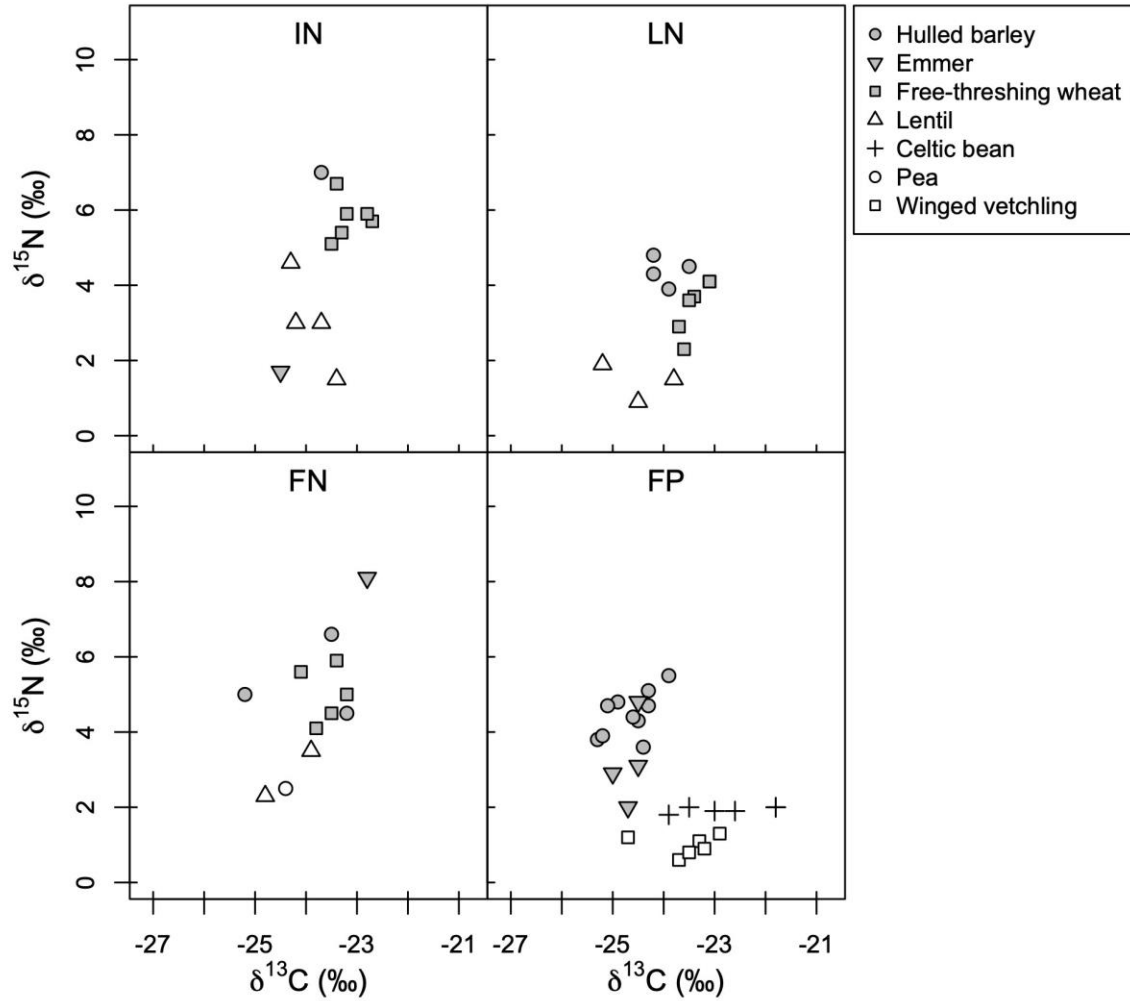


Figure 5

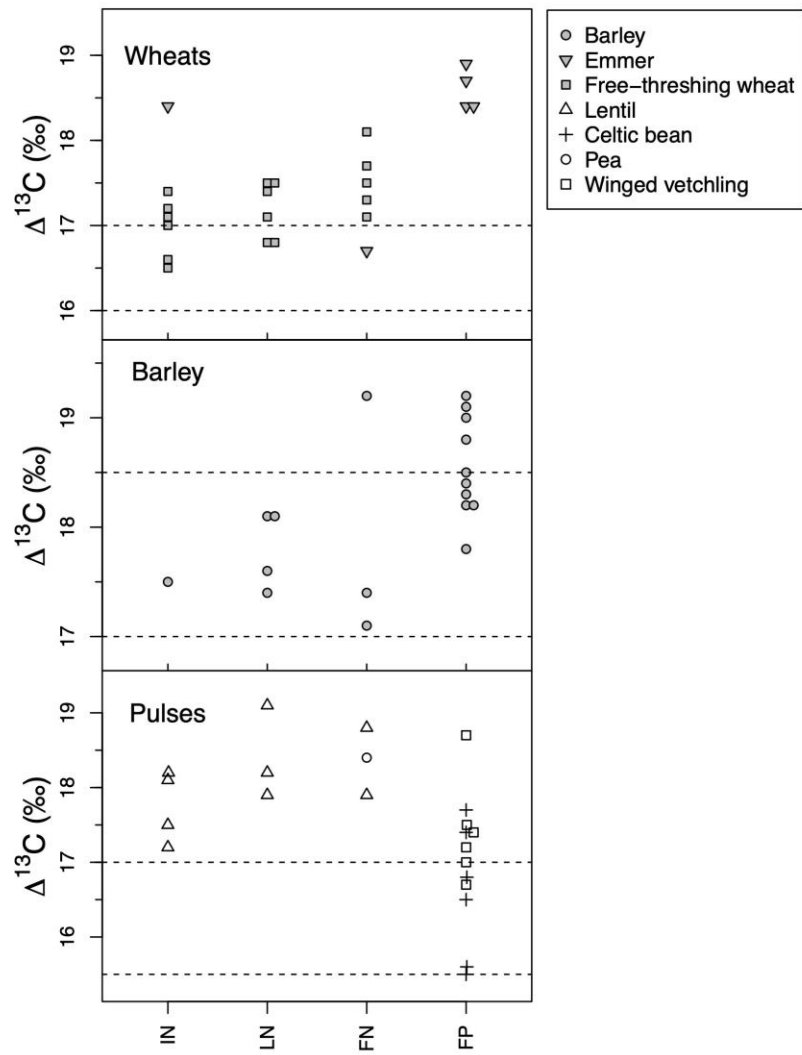
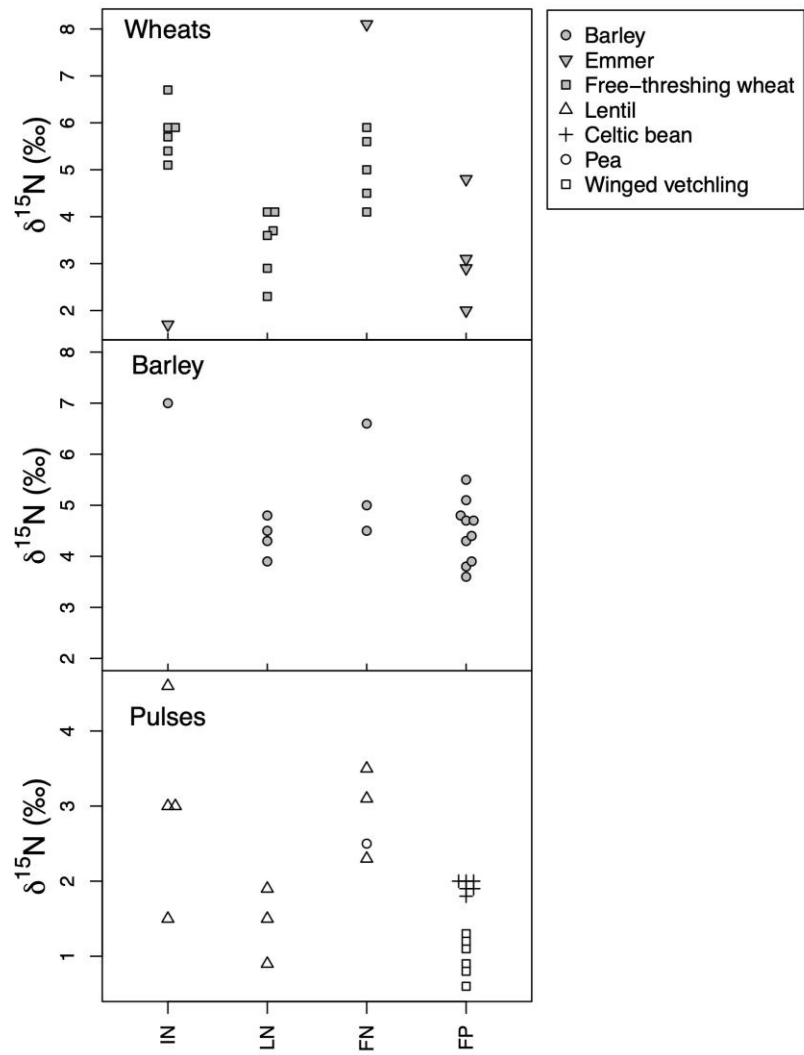
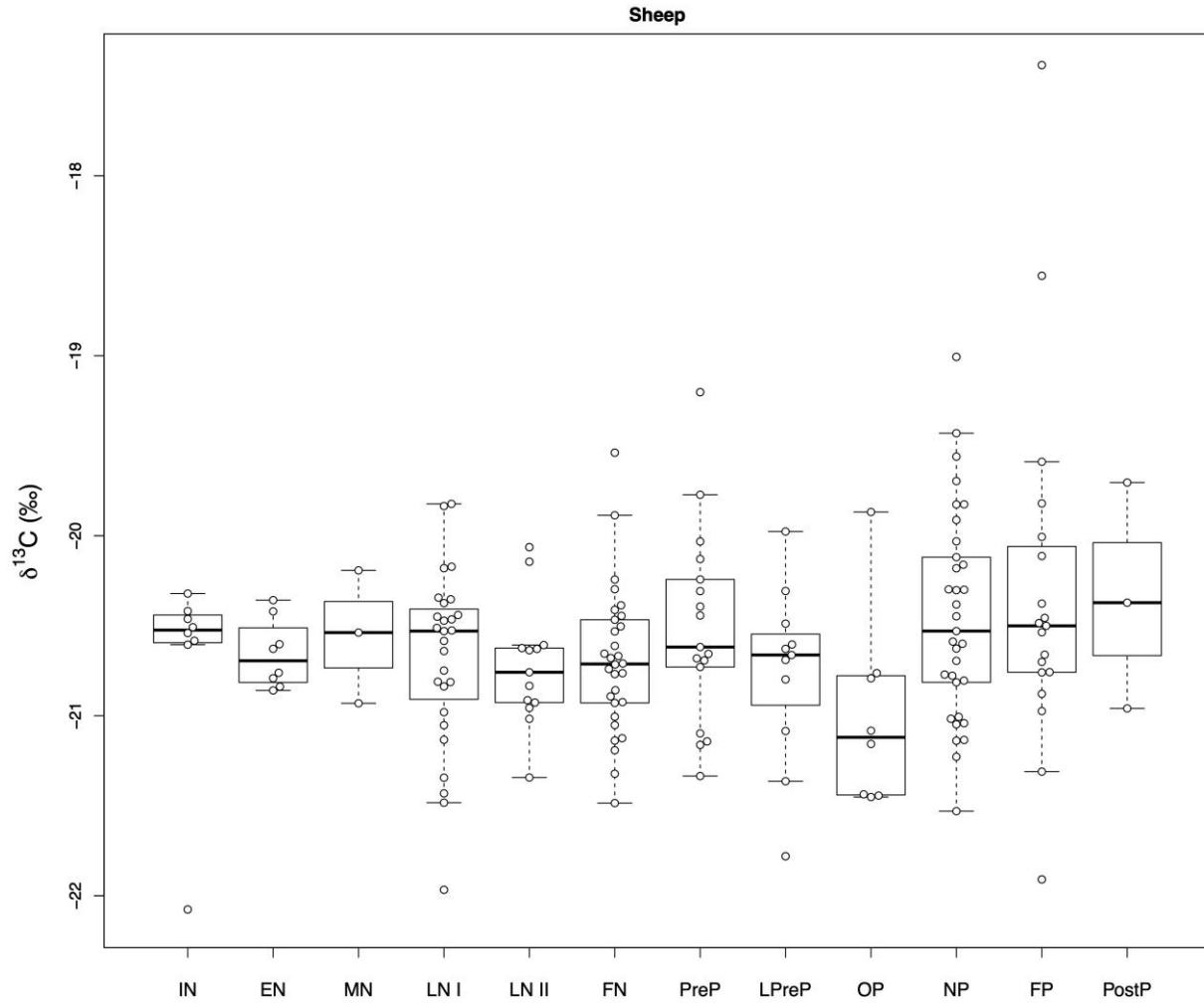


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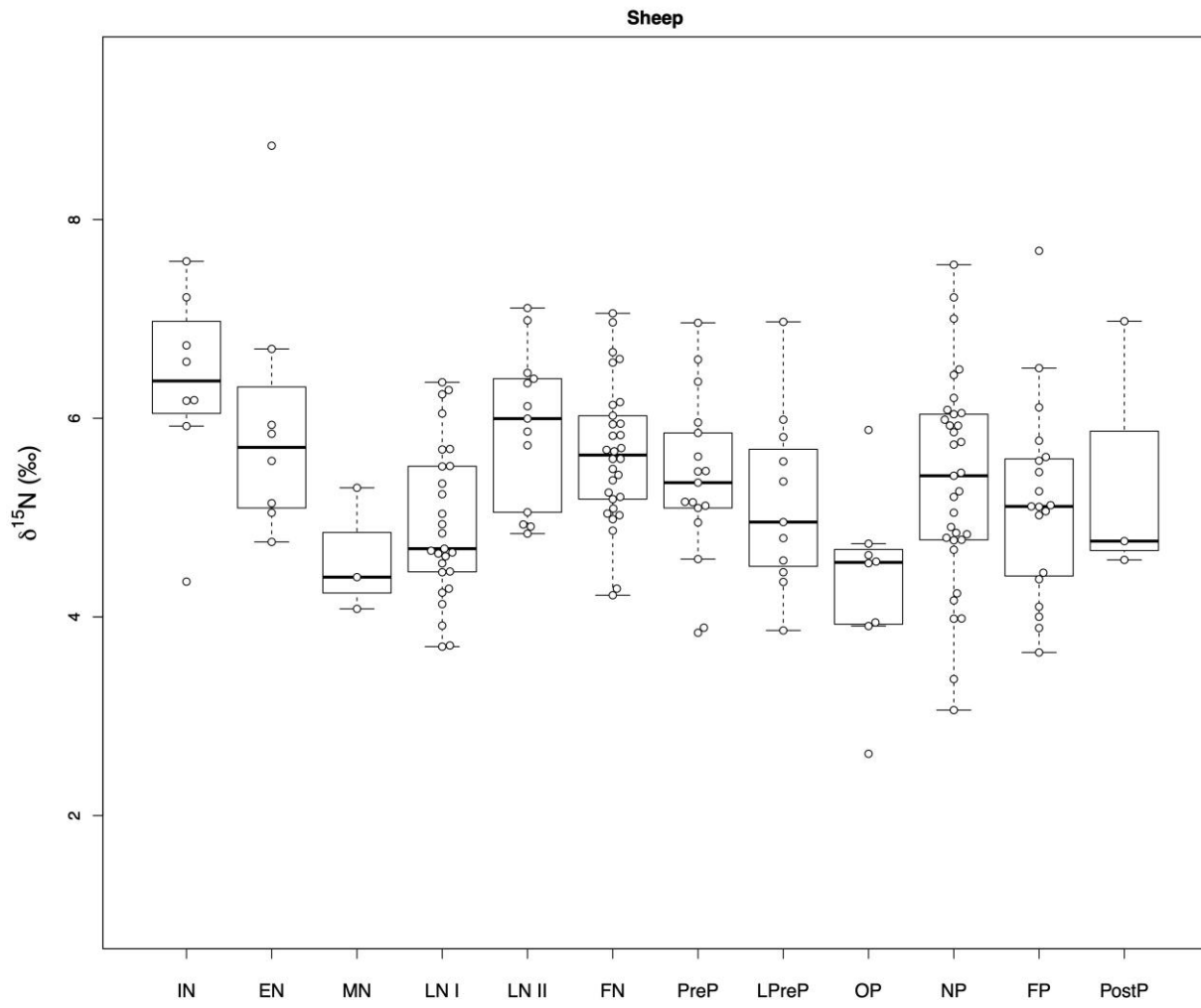


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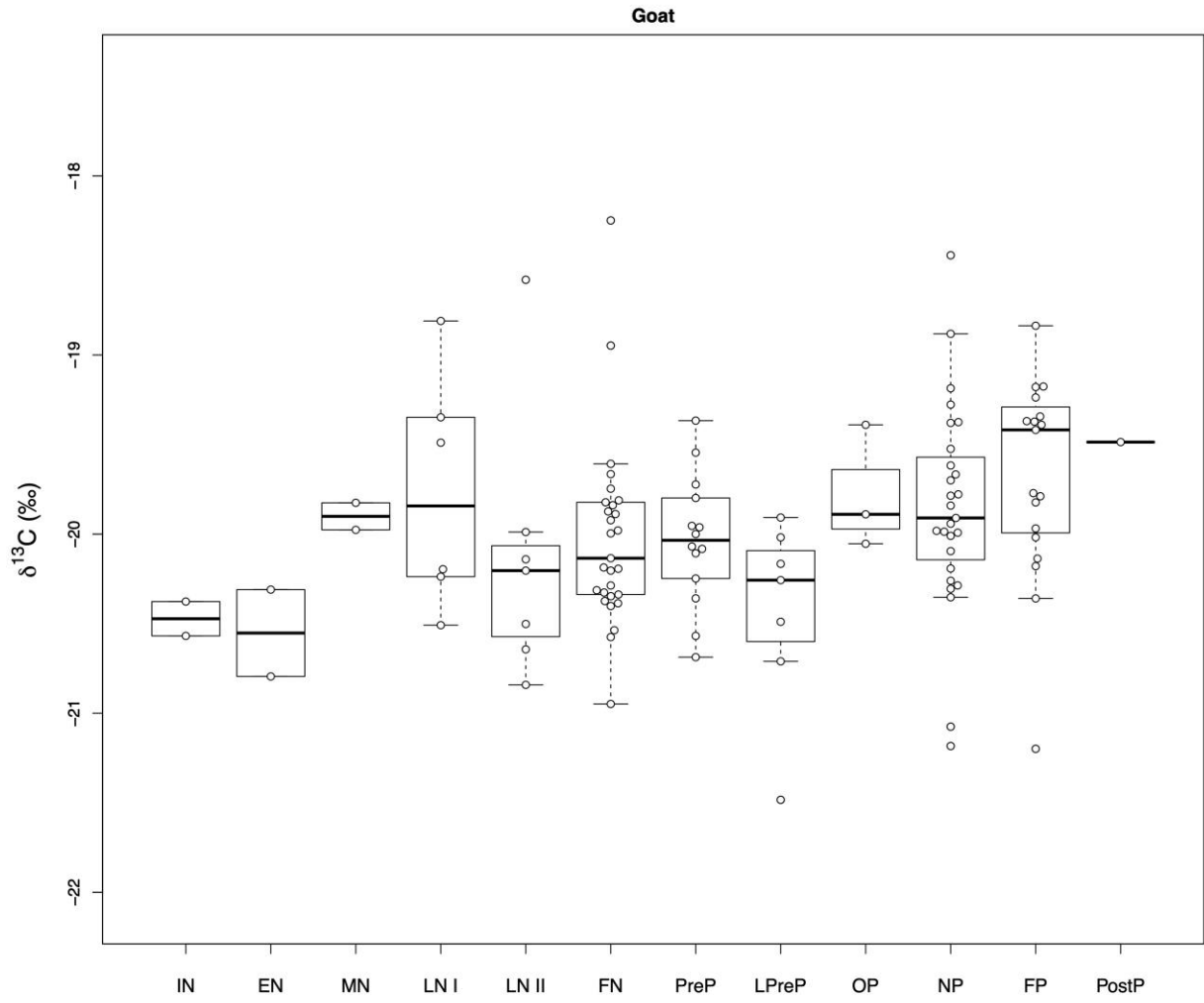
**a.**



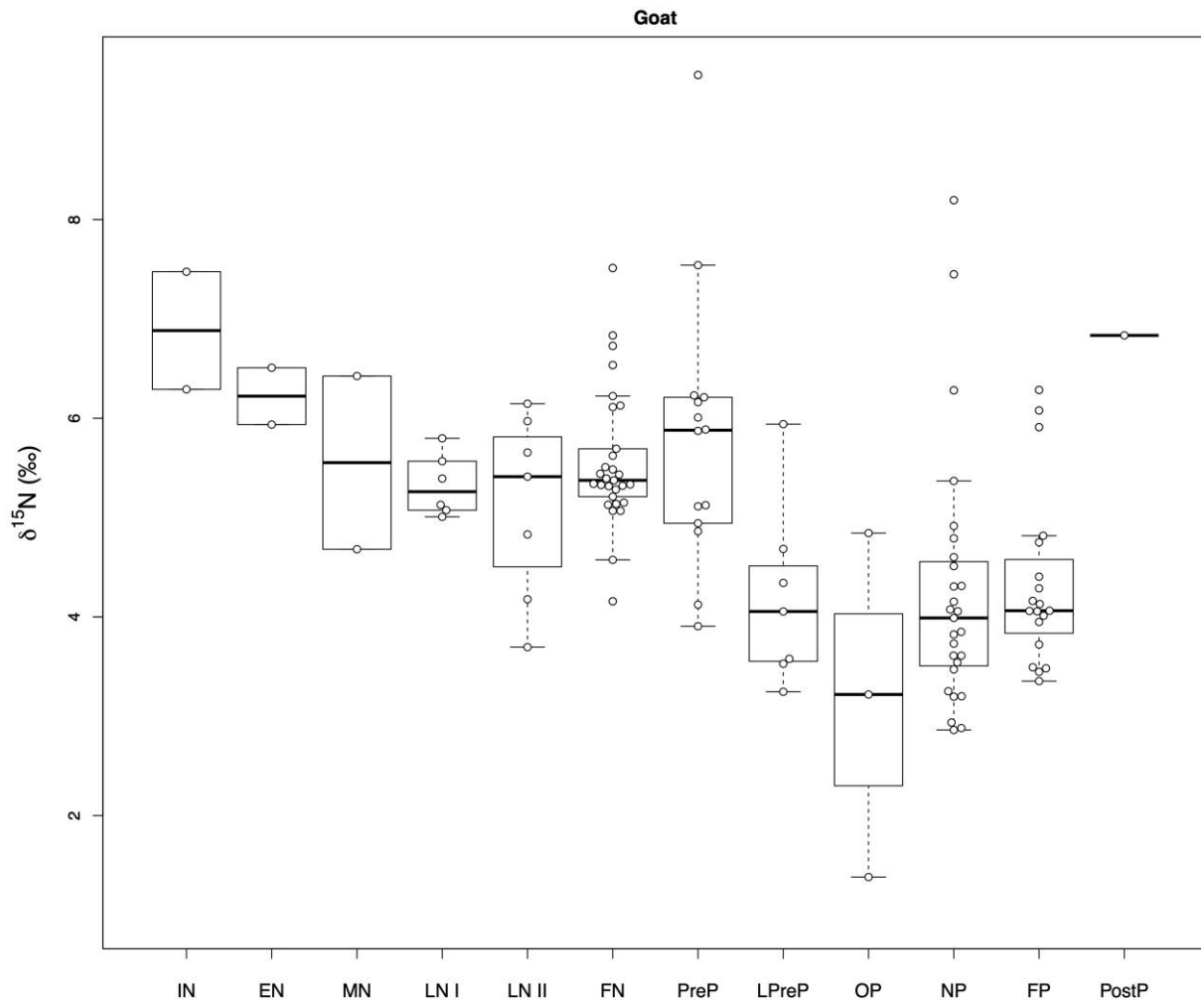
7b.



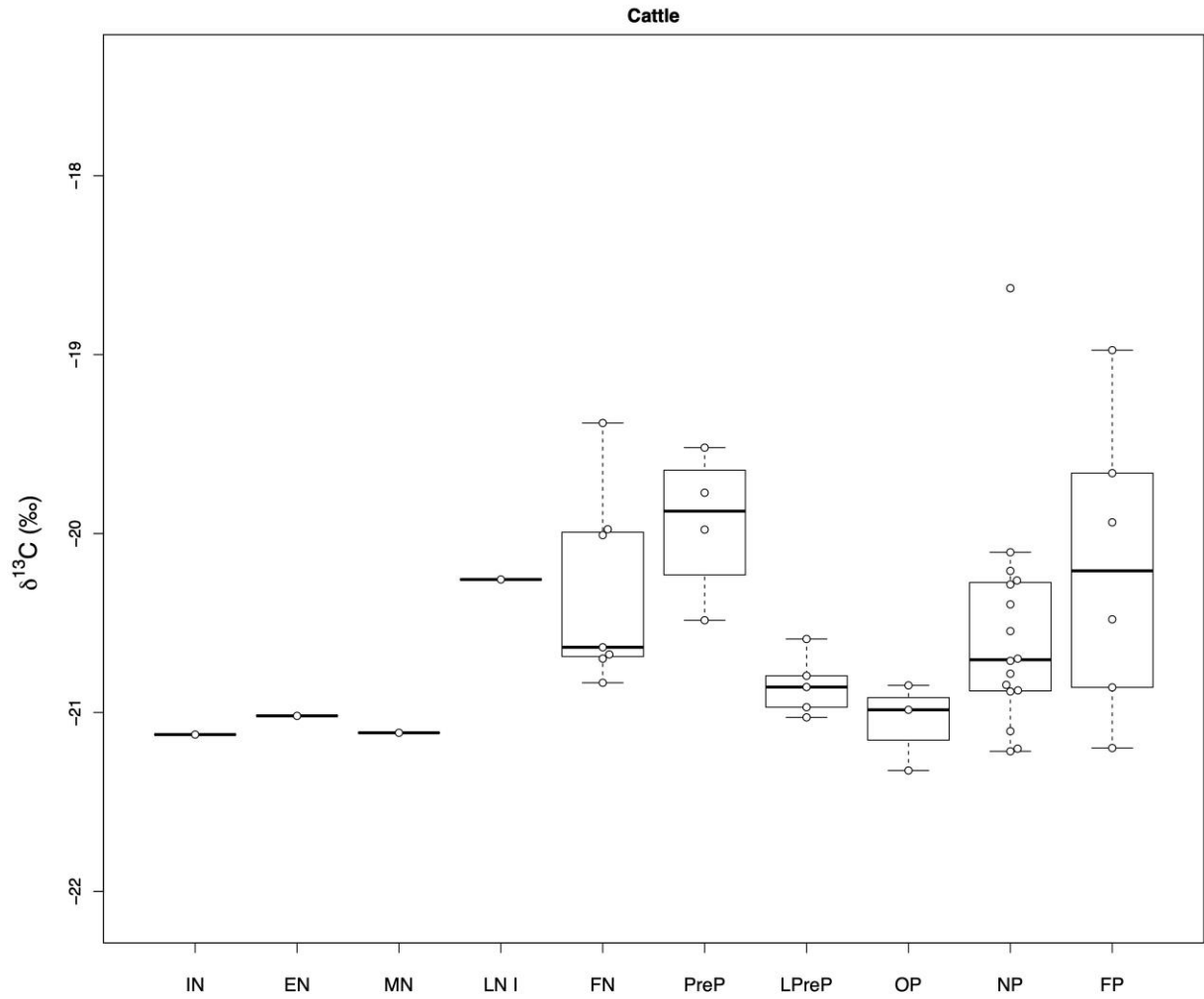
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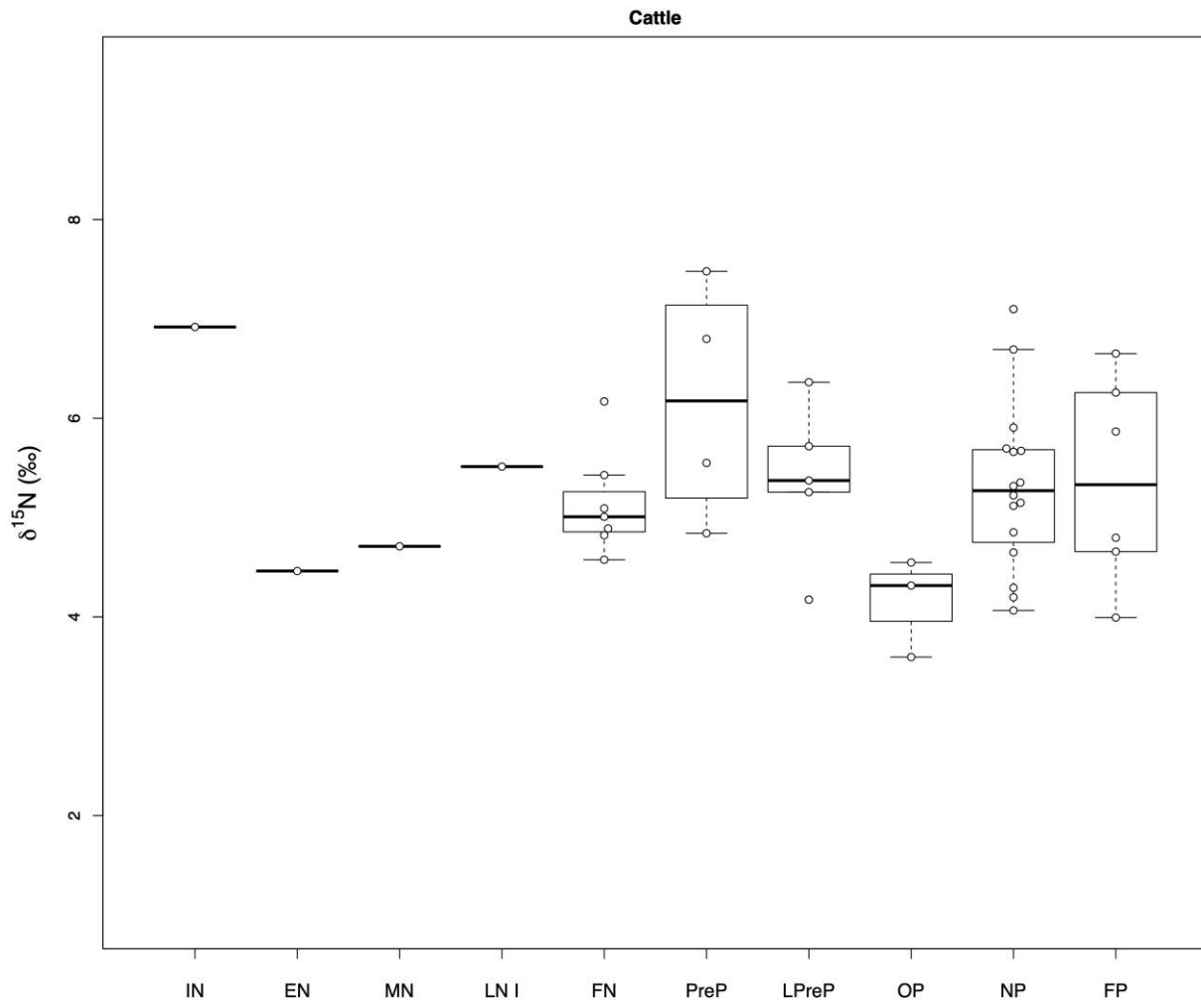
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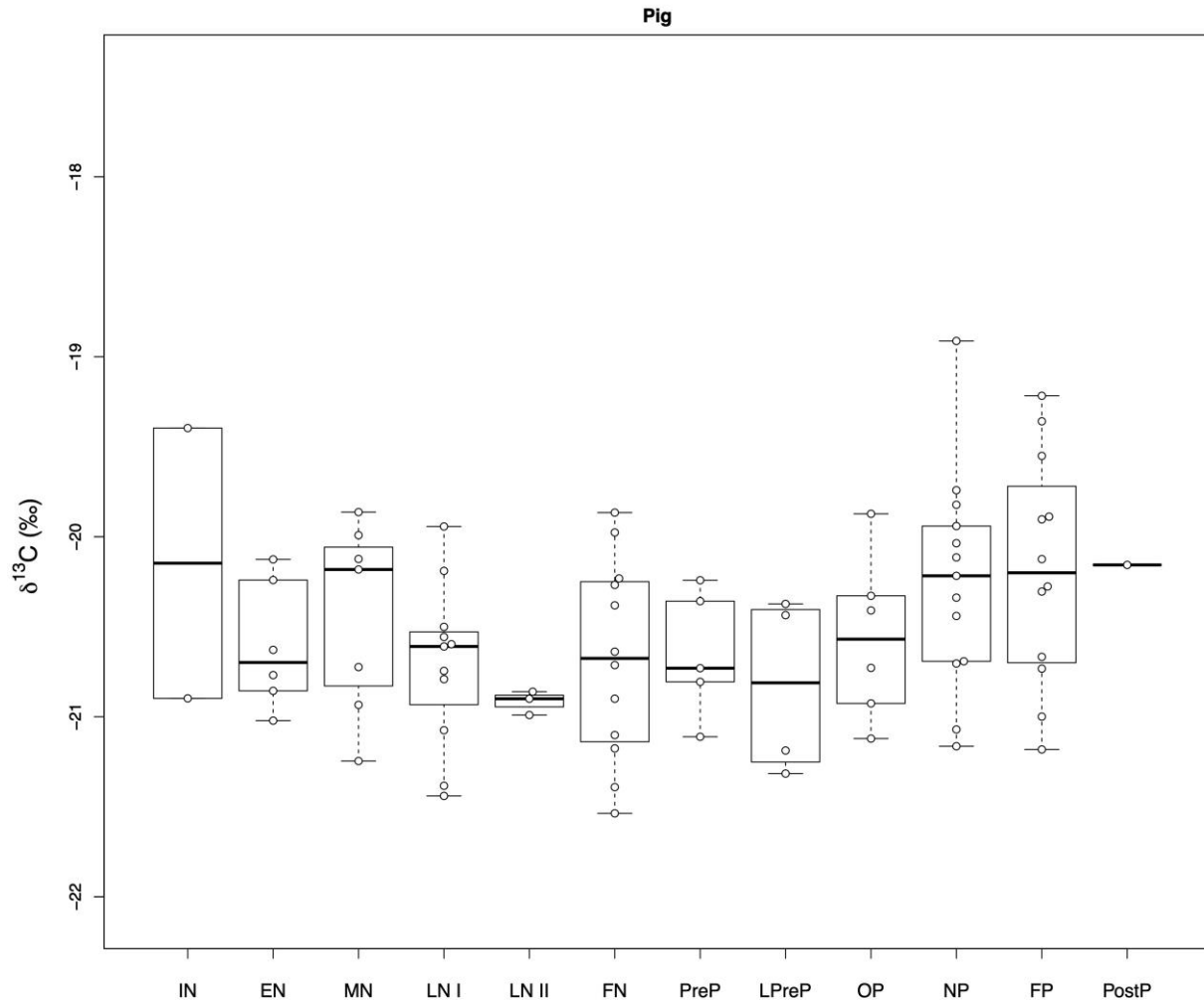
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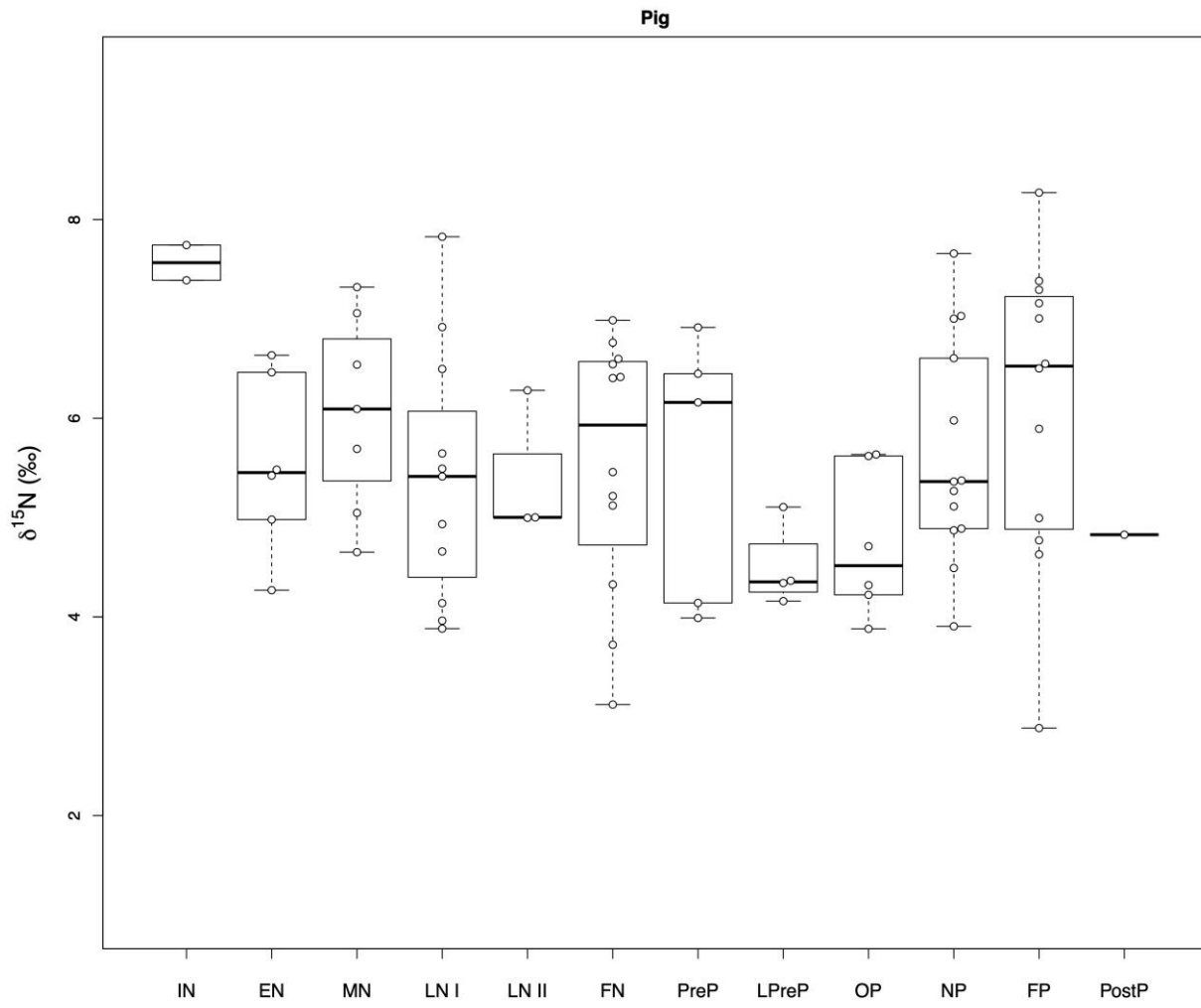
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7g.

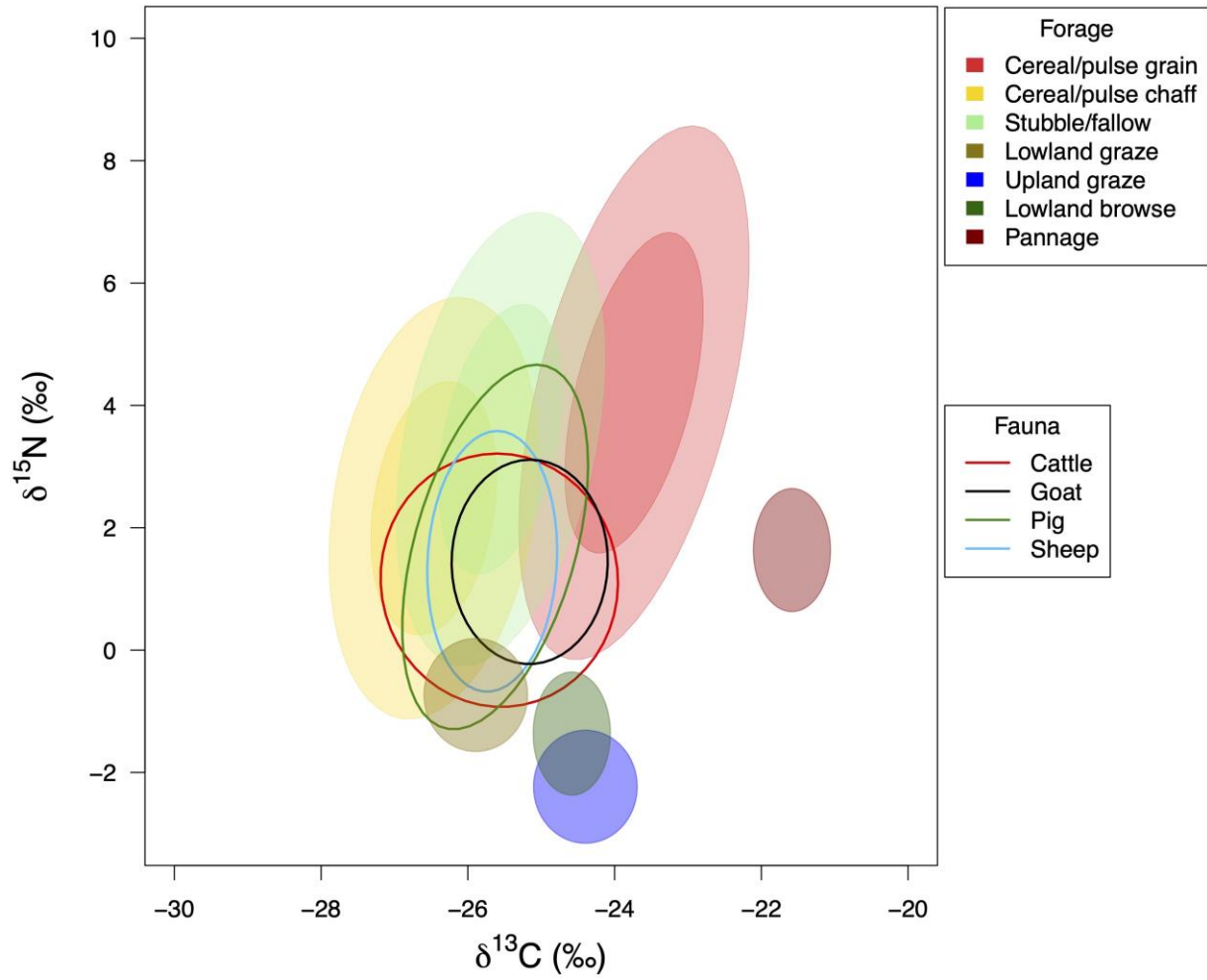


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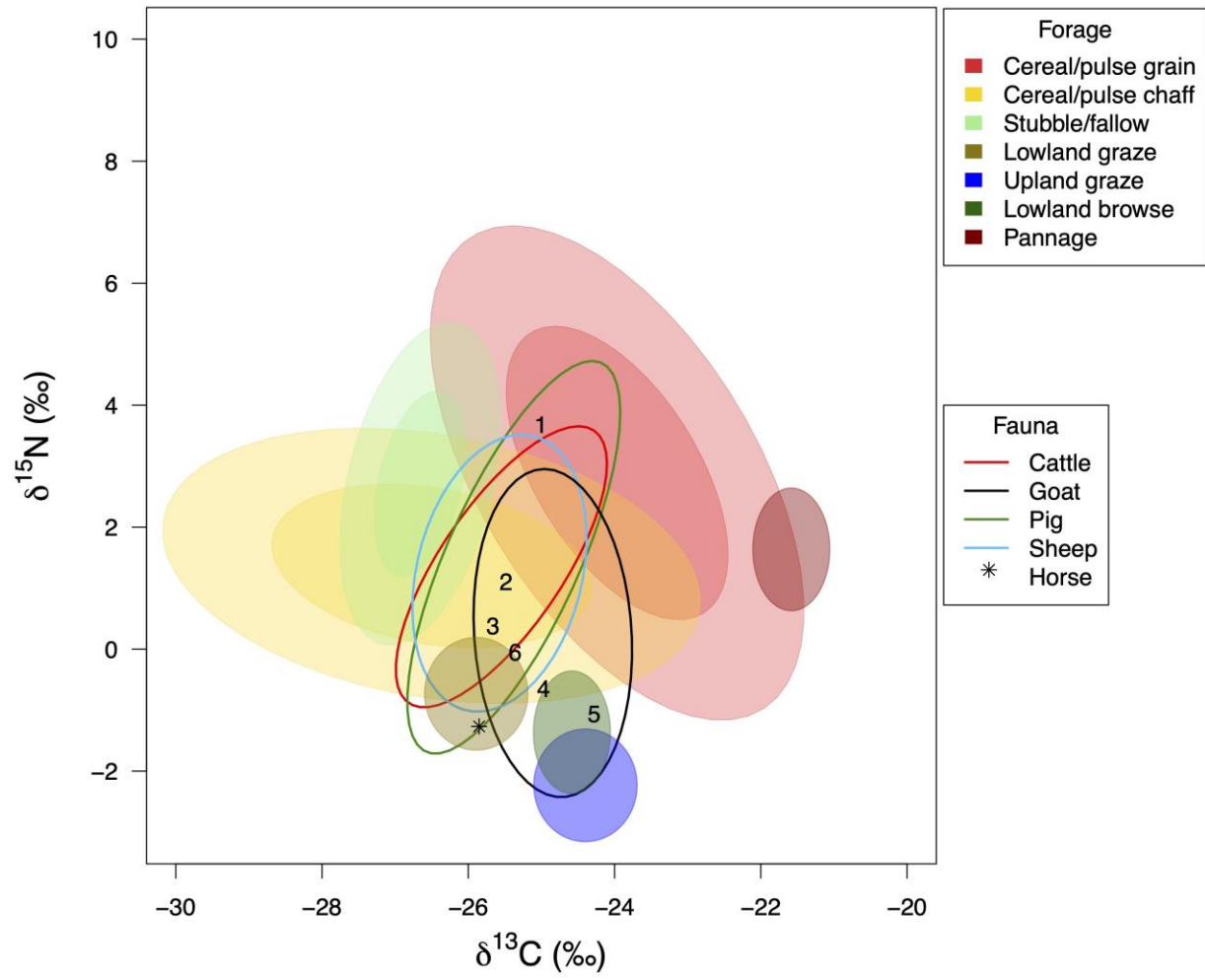


**Figure 8**

**a.**

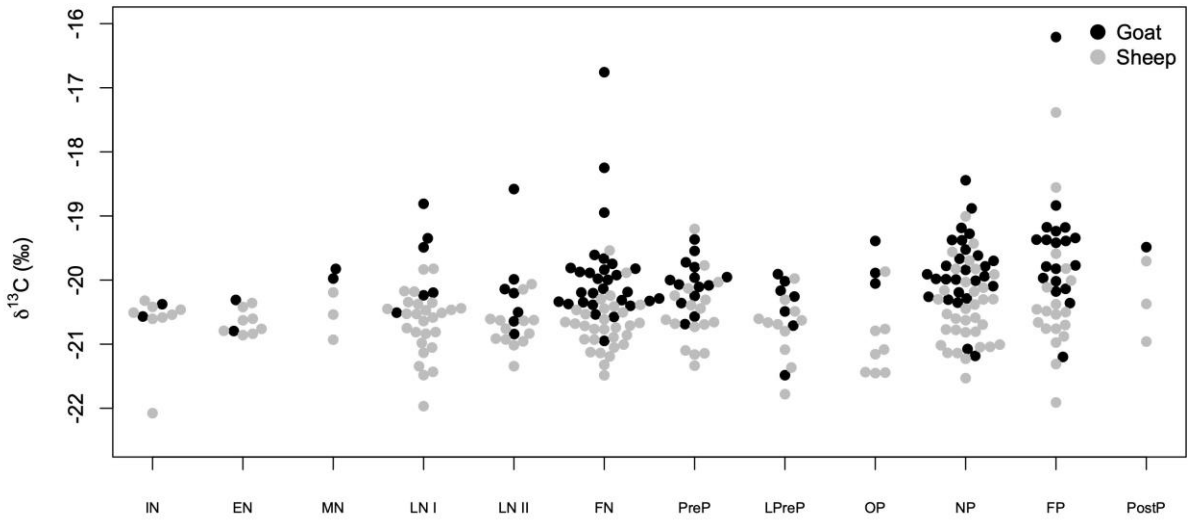


8b.



**Figure 9**

**a.**



9b.

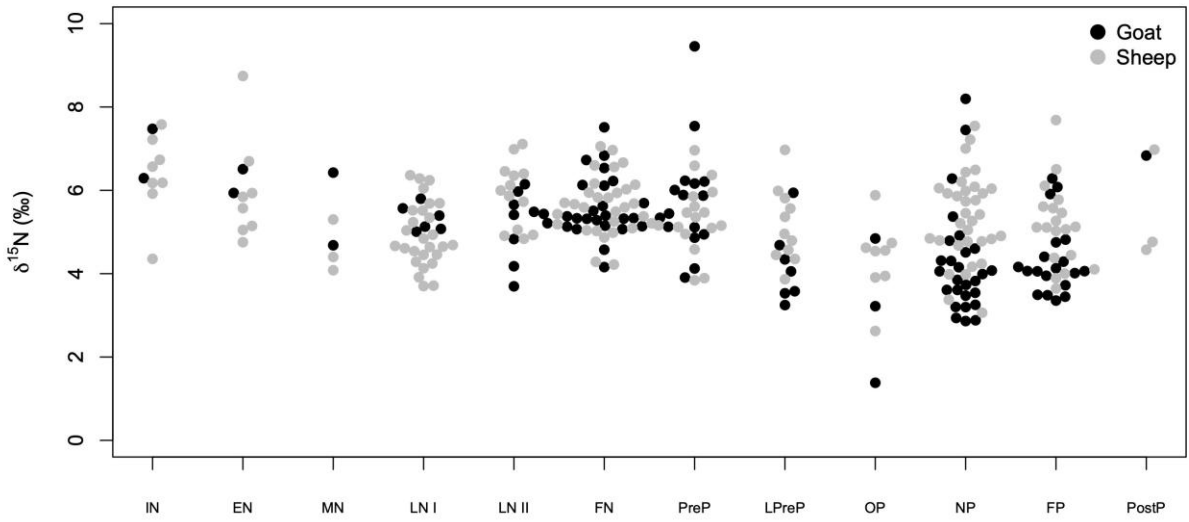
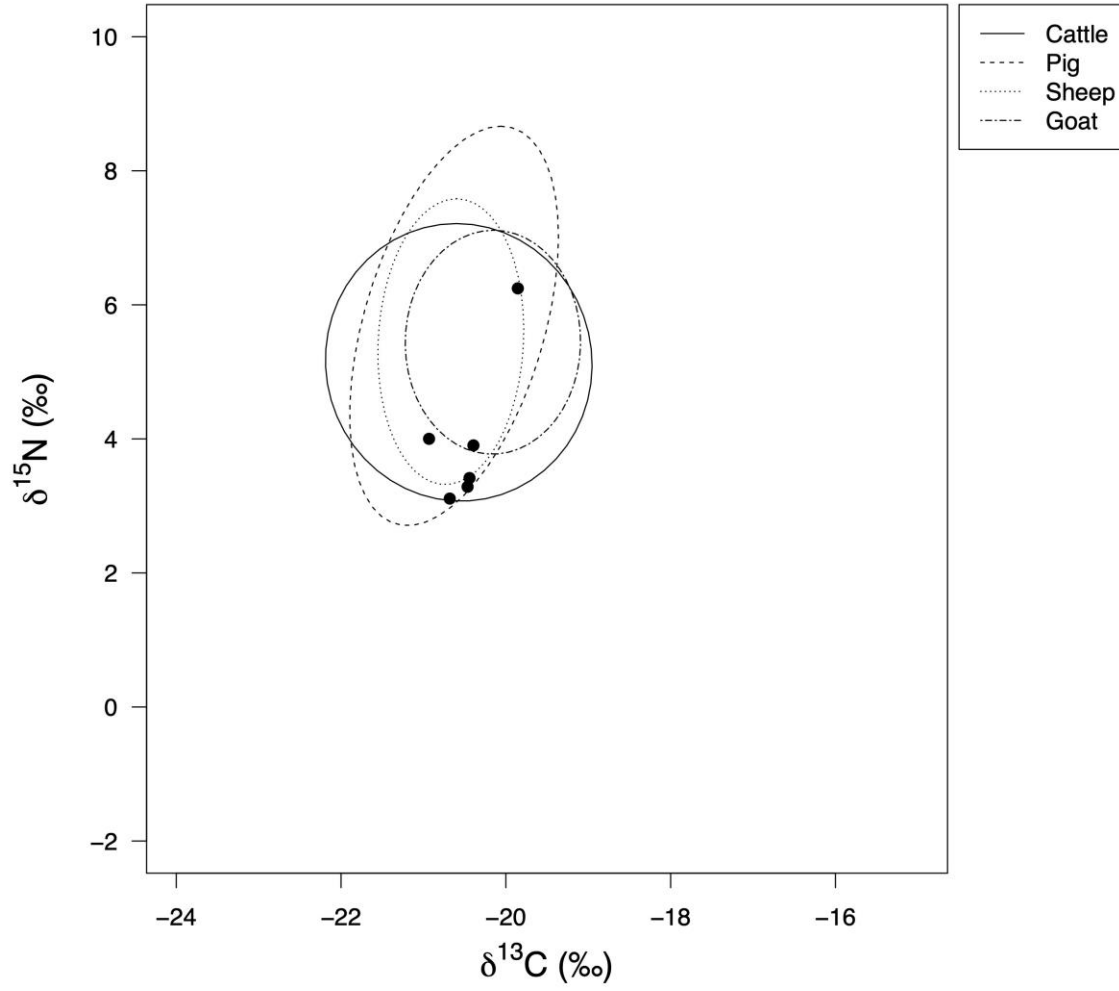


Figure 10

a.



10b.

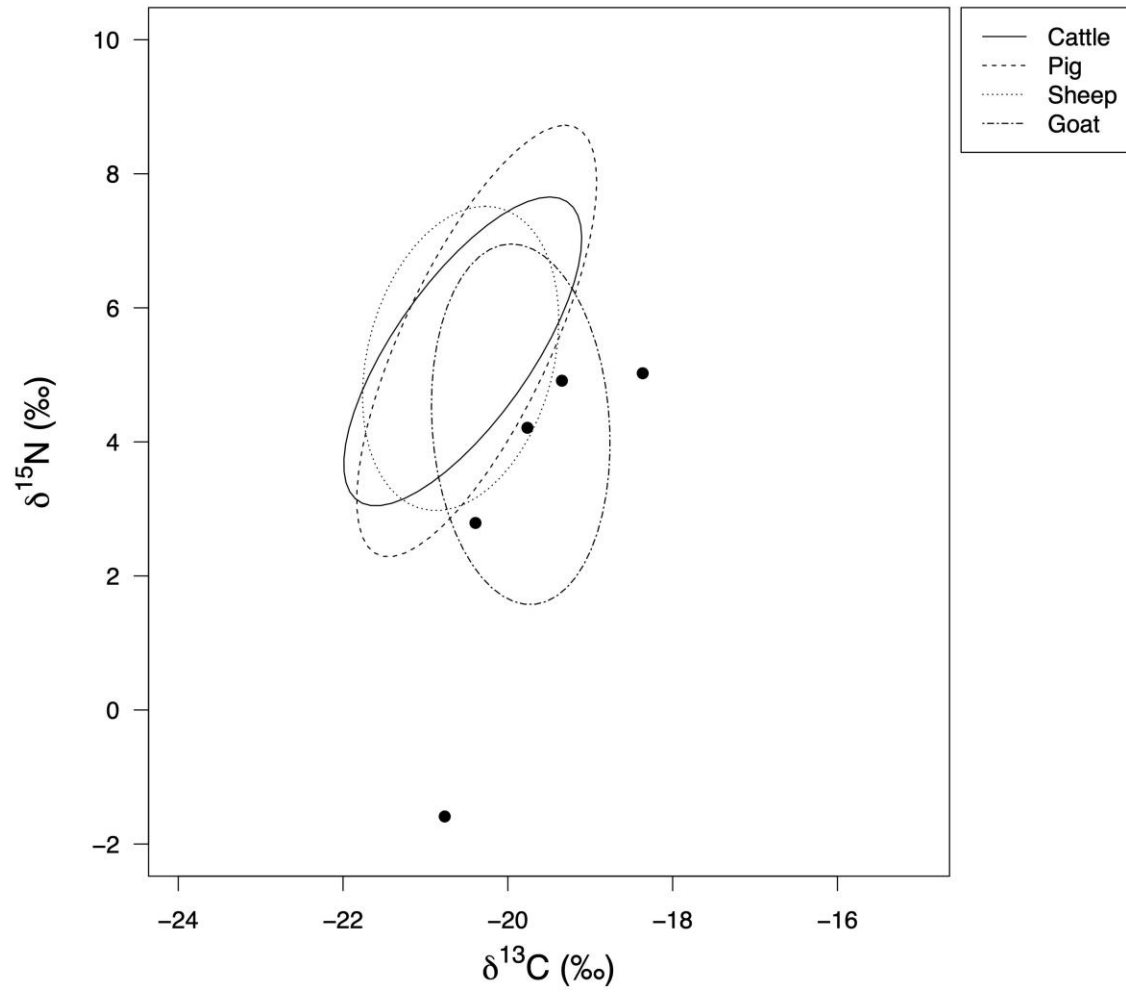


Figure 11

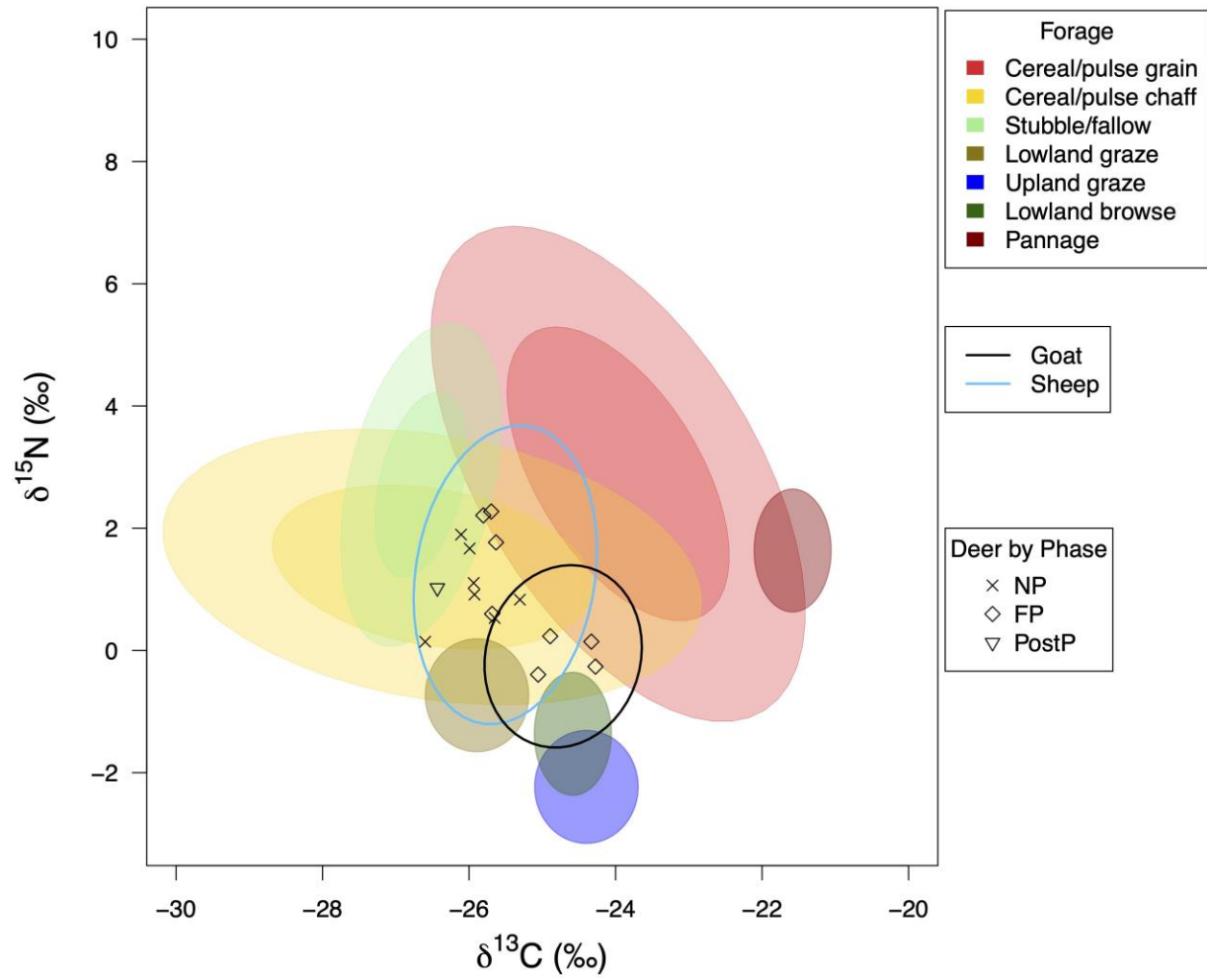


Figure 12

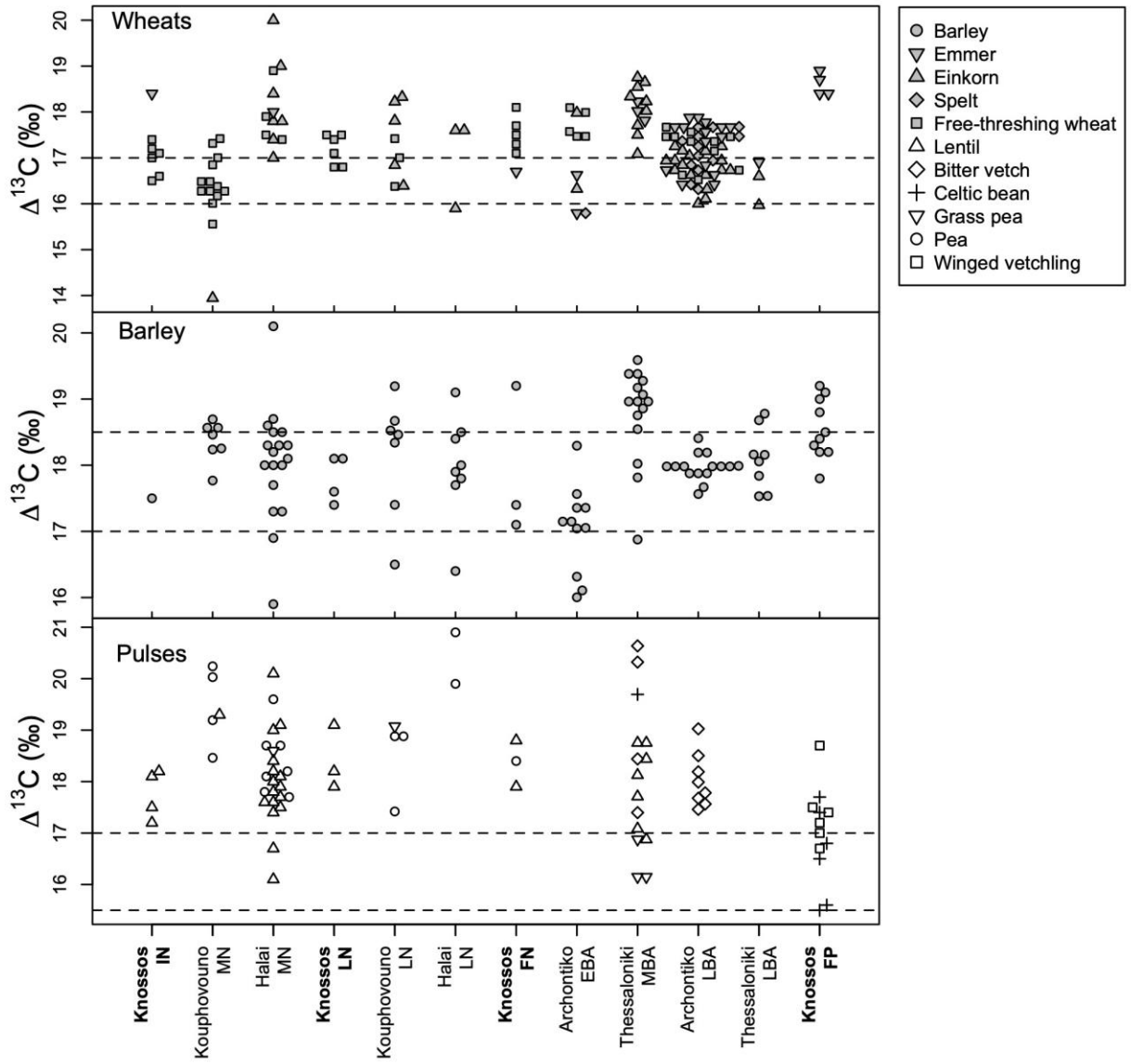


Figure 13

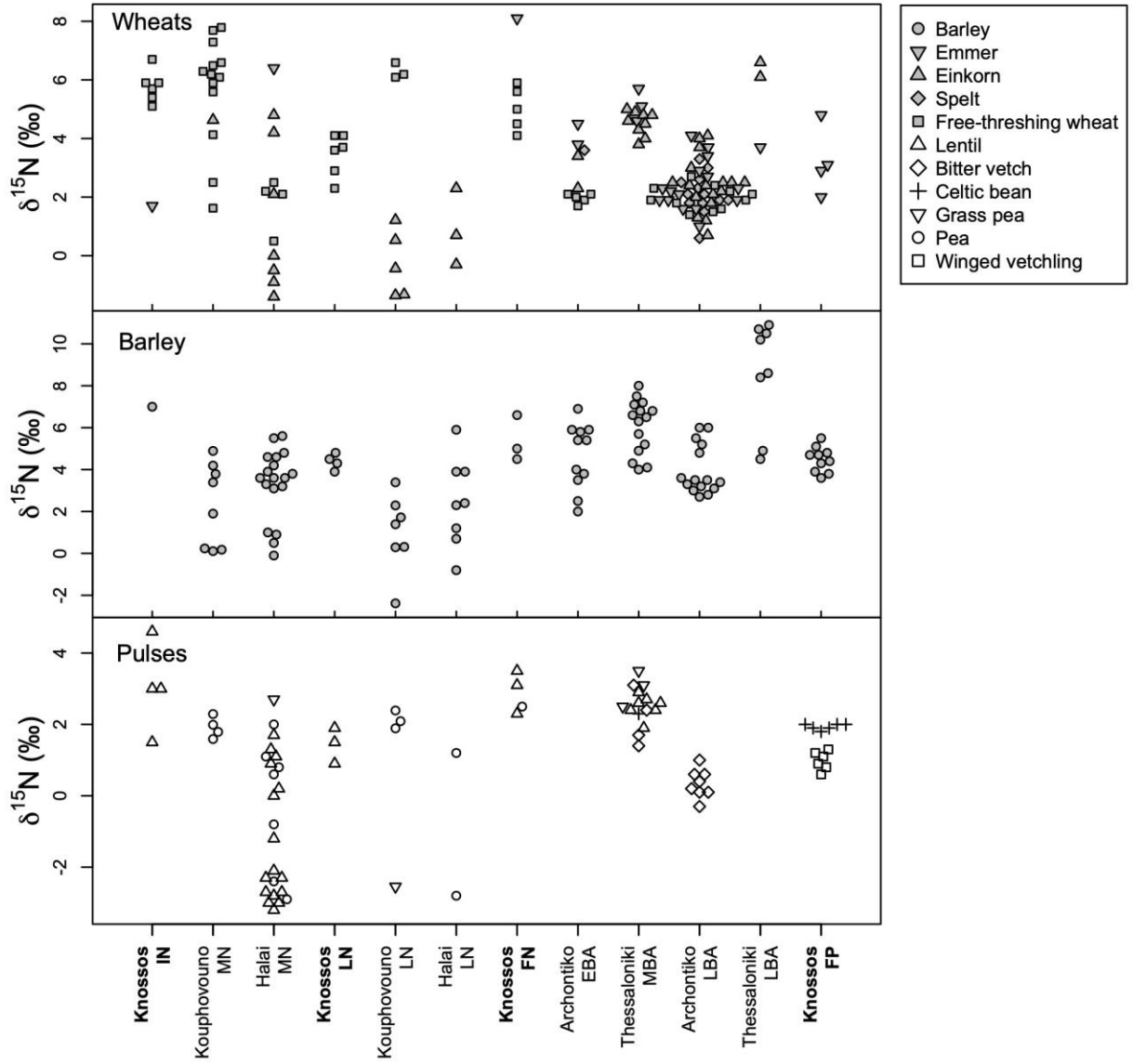
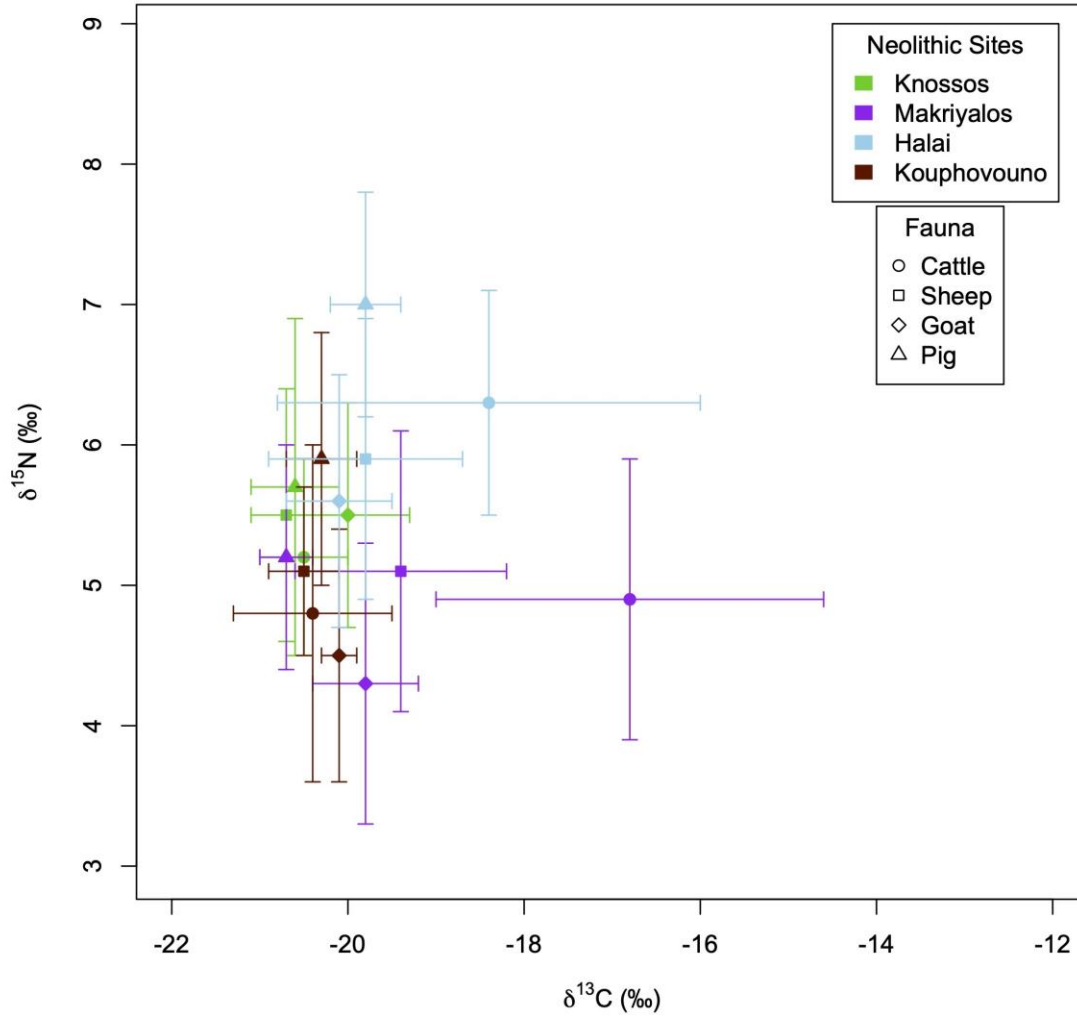


Figure 14

a.



14b.

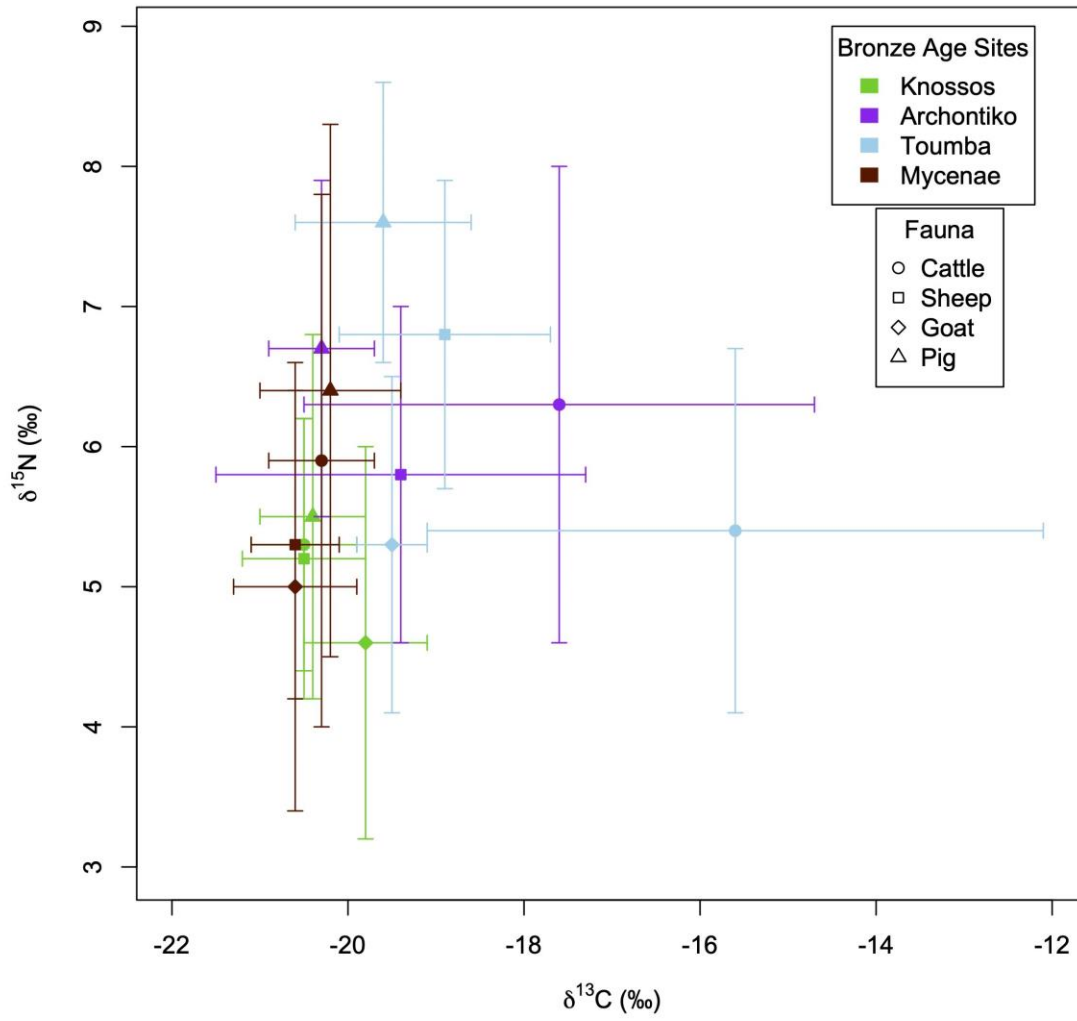


Table 1. Site phasing, absolute chronology and estimated settlement area and population size for prehistoric Knossos

Phase	Absolute date BC (approx.)	Habitation area (ha)	Population estimates
Initial Neolithic (IN)	7000-6500	0.3	30
Early Neolithic (EN)	6500-6000	0.3	30
Middle Neolithic (MN)	6000-5500	0.8	80
Late Neolithic I (LN I)	5500-5000	1.4-1.75	140-175
Late Neolithic II (LN II)	5000-4500	1.75-2.5/4.5	175-250/
Final Neolithic (FN)	4500-3500		450
Prepalatial (PreP) = EM I-EM II	3200-2500	6.5	1000-1300
Late Prepalatial (LPreP) = EM III-MM IA	2500-1900	40-65	4000-10,000
Old Palace (OP) = MM IB-MM II	1900-1750	63-76	12,500-15,000
New Palace (NP) = MM III-LM I	1750-1490	75-125	15,000-25,000
Final Palace (FP) = LM II-III A	1490-1300	60	12,000
Postpalatial (PostP) = LM IIIB-C	1300-1100	19	2000-3000

Phasing and chronology: for Neolithic after Tomkins 2020; for Bronze Age after Shelmerdine 2008, 4-5 figs. 1.1-1.2 ('high' LBA chronology)

Settlement area: for IN-FN after Tomkins 2008, tables 3.1-3.2; for LN II-PostP after Whitelaw *et al.* 2019, fig. 19 (for LN II-FN: lower estimates after Tomkins 2007 and higher after Whitelaw *et al.* 2019)

Population estimates assume, after Whitelaw *et al.* 2019, fig. 19, habitation densities (inferred from surviving architectural remains) of: Neolithic – 100 persons/ha; PreP – 150-200/ha; LPreP – 100-150/ha; OP-FP – 200/ha; PostP – 100-150/ha

Key: EM, MM, LM = Early, Middle and Late Minoan ceramic phases

Table 2. Summary statistics for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of cereal and pulse grains from Neolithic and Bronze Age Knossos

		<i>No.</i>	$\delta^{13}\text{C}_{(VPDB)}$				$\delta^{15}\text{N}_{(AIR)}$			
			<i>Min</i>	<i>Max</i>	<i>Average</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>	<i>Average</i>	<i>SD</i>
Neolithic	Cereal	27	-25.0	-22.5	-23.3	0.5	1.7	8.1	4.8	1.4
	Pulse	11*	-25.0	-23.2	-24.1	0.5	0.9	4.6	2.5	1.1
Bronze Age	Cereal	14	-25.1	-23.7	-24.5	0.4	2.0	5.5	4.1	1.0
	Pulse	12	-24.5	-21.6	-23.0	0.8	0.6	2.1	1.5	0.5
All	Cereal	41	-25.1	-22.5	-23.7	0.7	1.7	8.1	4.6	1.3
	Pulse	23	-25.0	-21.6	-23.4	0.9	0.6	4.6	2.0	1.0

(\*10 for  $\delta^{13}\text{C}$ )

SD = one standard deviation ( $1\sigma$ )

Table 3. Results of ANOVA and Welch two-sample t-test (denoted by \*) analysis of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of cereal and pulse grains from Neolithic and Bronze Age Knossos ( $\geq 3$  samples per test; only tests with significant P-value shown). Full details for post hoc test provided in Table S3

<i>Species</i>	<i>Phases</i>	<i>Isotope</i>	<i>df</i>	<i>F (t)</i>	<i>P-value</i>	<i>Post hoc differences</i>
Pulse, cereals*	All	$\delta^{15}\text{N}$	57.3	(9.07)	0.000	
Pulse, cereals*	Neolithic	$\delta^{13}\text{C}$	16.3	(3.3)	0.004	
Pulse, cereals*	Bronze Age	$\delta^{13}\text{C}$	15.3	(5.7213)	0.000	
Pulse*	Neolithic vs Bronze Age	$\delta^{13}\text{C}$	19.0	(3.607)	0.002	
Cereal*	Neolithic vs Bronze Age	$\delta^{13}\text{C}$	34.4	(7.3684)	0.000	
Barley, free-threshing wheat, lentil	Neolithic	$\delta^{13}\text{C}$	2(31)	9.62	0.001	Free-threshing wheat $\neq$ barley & lentil
Emmer, Celtic bean, barley, winged vetchling	Bronze Age	$\delta^{13}\text{C}$	3(22)	15.42	0.000	Celtic bean $\neq$ emmer & barley; winged vetchling $\neq$ emmer & barley
Free-threshing wheat, lentil*	IN	$\delta^{13}\text{C}$	5.35	(2.992)	0.028	
Free-threshing wheat, barley, lentil	LN vs FN	$\delta^{13}\text{C}$	2(10)	7.709	0.009	Lentil $\neq$ free-threshing wheat
'Wheat'*	FN vs LM II	$\delta^{13}\text{C}$	7.75	(5.4923)	0.001	
'Wheat'*	LM II vs IN	$\delta^{13}\text{C}$	8.50	(5.2703)	0.001	
'Wheat'*	LM II vs LN	$\delta^{13}\text{C}$	6.91	(8.125)	0.000	
'Wheat'*	IN vs LN	$\delta^{15}\text{N}$	8.50	(2.5778)	0.031	
'Wheat'*	LN vs FN	$\delta^{15}\text{N}$	7.37	(3.2034)	0.014	
'Wheat'*	FN vs LM II	$\delta^{15}\text{N}$	7.48	(2.8307)	0.024	
'Wheat'*	LM II vs IN	$\delta^{15}\text{N}$	8.24	(2.3613)	0.044	

'Wheat' = emmer and free-threshing wheat combined

Table 4. Summary statistics for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of animal bone collagen from Neolithic and Bronze Age Knossos

	<i>Phase</i>	<i>No.</i>	$\delta^{13}\text{C}_{(VPDB)}$					$\delta^{15}\text{N}_{(AIR)}$				
			<i>Mean</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i>	<i>SD</i>	<i>Median</i>	<i>Min</i>	<i>Max</i>
Sheep	IN	8	-20.7	0.6	-20.5	-22.1	-20.3	6.3	1.0	6.4	4.4	7.6
	EN	8	-20.7	0.2	-20.7	-20.9	-20.4	6.0	1.3	5.7	4.8	8.7
	MN	3	-20.6	0.4	-20.5	-20.9	-20.2	4.6	0.6	4.4	4.1	5.3
	LN I	27	-20.7	0.5	-20.5	-22.0	-19.8	4.9	0.8	4.7	3.7	6.4
	LN II	13	-20.7	0.3	-20.8	-21.3	-20.1	5.9	0.8	6.0	4.8	7.1
	FN	30	-20.7	0.4	-20.7	-21.5	-19.5	5.7	0.7	5.6	4.2	7.1
	<i>All Neolithic</i>	89	-20.7	0.4	-20.6	-22.1	-19.5	5.5	0.9	5.5	3.7	8.7
	PreP	17	-20.5	0.6	-20.6	-21.3	-19.2	5.4	0.8	5.4	3.8	7.0
	LPreP	11	-20.8	0.5	-20.7	-21.8	-20.0	5.2	0.9	5.0	3.9	7.0
	OP	8	-21.0	0.5	-21.1	-21.5	-19.9	4.4	0.9	4.6	2.6	5.9
	NP	33	-20.4	0.6	-20.5	-21.5	-19.0	5.4	1.0	5.4	3.1	7.5
	FP	19	-20.3	1.0	-20.5	-21.9	-17.4	5.2	1.0	5.1	3.6	7.7
	PostP	3	-20.4	0.6	-20.4	-21.0	-19.7	5.4	1.3	4.8	4.6	7.0
	<i>All Bronze Age</i>	91	-20.5	0.7	-20.6	-21.9	-17.4	5.2	1.0	5.1	2.6	7.7
Goat	IN	2	-20.5	0.1	-20.5	-20.6	-20.4	6.9	0.8	6.9	6.3	7.5
	EN	2	-20.6	0.3	-20.6	-20.8	-20.3	6.2	0.4	6.2	5.9	6.5
	MN	2	-19.9	0.1	-19.9	-20.0	-19.8	5.6	1.2	5.6	4.7	6.4
	LN I	6	-19.8	0.7	-19.8	-20.5	-18.8	5.3	0.3	5.3	5.0	5.8
	LN II	7	-20.1	0.7	-20.2	-20.8	-18.6	5.1	0.9	5.4	3.7	6.1
	FN	29	-19.9	0.8	-20.1	-20.9	-16.8	5.6	0.7	5.4	4.2	7.5
	<i>All Neolithic</i>	48	-20.0	0.7	-20.2	-21.0	-16.8	5.6	0.8	5.4	3.7	7.5
	PreP	14	-20.0	0.4	-20.0	-20.7	-19.4	5.8	1.4	5.9	3.9	9.5
	LPreP	7	-20.4	0.5	-20.3	-21.5	-19.9	4.2	0.9	4.1	3.3	5.9

Cattle	OP	3	-19.8	0.4	-19.9	-20.1	-19.4	3.2	1.7	3.2	1.4	4.8
	NP	27	-19.9	0.6	-19.9	-21.2	-18.4	4.3	1.3	4.0	2.9	8.2
	FP	19	-19.5	1.0	-19.4	-21.2	-16.2	4.3	0.9	4.1	3.4	6.3
	PostP	1	-19.5					6.8				
	<i>All Bronze Age</i>	71	-19.8	0.7	-19.9	-21.5	-16.2	4.6	1.4	4.2	1.4	9.5
	IN	1	-21.1					6.9				
	EN	1	-21.0					4.5				
	MN	1	-21.1					4.7				
	LN I	1	-20.3					5.5				
	FN	7	-20.3	0.5	-20.6	-20.8	-19.4	5.1	0.5	5.0	4.6	6.2
	<i>All Neolithic</i>	11	-20.5	0.6	-20.7	-21.1	-19.4	5.2	0.7	5.0	4.5	6.9
	PreP	4	-19.9	0.4	-19.9	-20.5	-19.5	6.2	1.2	6.2	4.8	7.5
	LPreP	5	-20.9	0.2	-20.9	-21.0	-20.6	5.4	0.8	5.4	4.2	6.4
	OP	3	-21.1	0.2	-21.0	-21.3	-20.9	4.2	0.5	4.3	3.6	4.6
	NP	16	-20.6	0.6	-20.7	-21.2	-18.6	5.3	0.8	5.3	4.1	7.1
FP	6	-20.2	0.8	-20.2	-21.2	-19.0	5.4	1.0	5.3	4.0	6.7	
<i>All Bronze Age</i>	34	-20.5	0.6	-20.7	-21.3	-18.6	5.3	1.0	5.3	3.6	7.5	
Pig	IN	2	-20.1	1.1		-20.9	-19.4	7.6	0.3		7.4	7.7
	EN	6	-20.6	0.4	-20.7	-21.0	-20.1	5.5	0.9	5.5	4.3	6.6
	MN	7	-20.4	0.5	-20.2	-21.2	-19.9	6.1	1.0	6.1	4.7	7.3
	LN I	11	-20.7	0.5	-20.6	-21.4	-19.9	5.4	1.3	5.4	3.9	7.8
	LN II	3	-20.9	0.1	-20.9	-21.0	-20.9	4.5	0.4	4.4	4.2	5.1
	FN	12	-20.7	0.6	-20.7	-21.5	-19.9	5.6	1.3	5.9	3.1	7.0
	<i>All Neolithic</i>	41	-20.6	0.5	-20.7	-21.5	-19.4	5.7	1.2	5.5	3.1	7.8
	PreP	5	-20.6	0.4	-20.7	-21.1	-20.2	5.5	1.4	6.2	4.0	6.9
	LPreP	4	-20.8	0.5	-20.8	-21.3	-20.4	4.5	0.4	4.4	4.2	5.1
	OP	6	-20.6	0.5	-20.6	-21.1	-19.9	4.7	0.7	4.5	3.9	5.6
	NP	13	-20.2	0.6	-20.2	-21.2	-18.9	5.7	1.1	5.4	3.9	7.7

Fallow deer	FP	12	-20.2	0.6	-20.2	-21.2	-19.2	6.1	1.5	6.5	2.9	8.3	
	PostP	1	-20.2					4.8					
	<i>All Bronze Age</i>	41	-20.4	0.6	-20.4	-21.3	-18.9	5.5	1.3	5.3	2.9	8.3	
	NP	7	-20.6	0.4	-20.9	-21.6	-20.3	5.0	0.6	4.9	4.1	5.9	
	FP	8	-20.2	0.6	-20.3	-20.8	-19.3	4.8	1.1	4.4	3.6	6.3	
	PostP	1	-21.4					5.0					
	Horse	<i>Bronze Age</i>	1	-20.9					2.7				
	Badger	<i>Neolithic</i>	1	-19.8					5.7				
		<i>Bronze Age</i>	2	-19.6	1.6		-18.5	-20.8	6.8	2.8		4.8	8.8
	Dog	<i>Neolithic</i>	6	-19.5	0.4	-19.5	-19.9	-18.9	8.0	1.2	7.7	7.1	10.3
		<i>Bronze Age</i>	5	-18.7	0.9	-18.8	-19.8	-17.4	7.1	2.8	8.2	2.4	9.0

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SD = one standard deviation ( $1\sigma$ )

Table 5. Results of ANOVA analysis of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of animal bone collagen from Neolithic and Bronze Age Knossos (only tests with significant P-value shown); full details for Tukey post hoc test provided in Table S5

<i>Species</i>	<i>Phases</i>	<i>Isotope</i>	<i>df</i>	<i>F</i>	<i>P-value</i>	<i>Post-hoc differences</i>
Goat***	LN II, FN, PreP, NP, FP	$\delta^{15}\text{N}$	6(100)	11.93	0.000	NP from LN I, LN II; FN from LPreP, NP, FP; PreP from LPreP, NP, FP
Sheep*	IN, EN, LN I, LN II, FN, PreP, LPreP, OP, NP, FP	$\delta^{15}\text{N}$	9(164)	4.26	0.000	LN I from IN; OP from IN, EN, LN II, FN
Sheep, goat, pig**	LN I	$\delta^{13}\text{C}$	2(41)	8.58	0.000	goat from sheep, pig
Sheep, goat, cattle, pig**	FN	$\delta^{13}\text{C}$	2(74)	9.28	0.000	goat from sheep, pig
Sheep, goat, pig**	PreP	$\delta^{13}\text{C}$	2(33)	5.38	0.009	goat from sheep, pig
Sheep, goat, cattle, pig***	NP	$\delta^{13}\text{C}$	3(83)	5.97	0.001	goat from sheep, cattle
Sheep, goat, cattle, pig***	NP	$\delta^{15}\text{N}$	3(83)	13.74	0.000	goat from sheep, cattle, pig
Sheep, goat, cattle, pig**	FP	$\delta^{13}\text{C}$	3(52)	2.80	0.049	goat from sheep
Sheep, goat, cattle, pig**	FP	$\delta^{15}\text{N}$	3(52)	6.59	0.001	goat from pig

\*  $\geq 5$  samples per phase

\*\*  $\geq 5$  samples per species

\*\*\*  $\geq 5$  samples per phase; excluding two mandibles of unweaned goats

## SUPPLEMENTARY MATERIAL

### S1. INTERPRETATION OF $\delta^{13}\text{C}$ AND $\delta^{15}\text{N}$ VALUES OF $\text{C}_3$ GRAIN CROPS IN RELATION TO CHANGING LAND USE

Plant  $\delta^{13}\text{C}$  values reflect photosynthetic pathway, being higher in  $\text{C}_4$  than  $\text{C}_3$  plants (O’Leary 1981). Among  $\text{C}_3$  plants (including the sampled cereal and pulse crops from Knossos and most plants available to the sampled fauna), they also reflect growing-season water availability, being higher in arid conditions (Farquhar *et al.* 1989). Water availability to crops reflects climate and local topography/geology, but also husbandry practices including irrigation. For example, in Mediterranean experiments,  $\delta^{13}\text{C}$  values are higher for unirrigated than fully irrigated free-threshing wheat (*Triticum aestivum* and *T. durum*) and broad bean (*Vicia faba*) by roughly 1 and 2‰, respectively (Wallace *et al.* 2013, 11 fig. 3). Absolute  $\delta^{13}\text{C}$  values differ between species, however, being 1‰ lower for two-row (*Hordeum vulgare* var. *distichon*) and perhaps 2‰ lower for six-row hulled barley (*Hordeum vulgare* var. *hexastichon*) than for free-threshing wheat with similar water availability (Anyia *et al.* 2007; Flohr *et al.* 2011; Wallace *et al.* 2013; cf. Styring *et al.* 2016a). Moreover, while broadly similar for lentil and wheat grown under similar conditions,  $\delta^{13}\text{C}$  values may be more sensitive to late-season drought in lentil (Wallace *et al.* 2013).

Plant  $\delta^{13}\text{C}$  values depend on that of atmospheric  $\text{CO}_2$ , which has decreased over the last 10,000 years (Francey *et al.* 1999; Indermühle *et al.* 1999), and so are routinely converted to  $\Delta^{13}\text{C}$  when comparing ancient and modern plant values (Farquhar *et al.* 1982):

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

Grain  $\Delta^{13}\text{C}$  values of  $\geq 17\text{‰}$  for free-threshing wheat and lentil and  $\geq 18.5\text{‰}$  for hulled barley (assuming an offset from wheat equivalent to a mixture of modern two- and six-row barley) may be regarded as well watered and of  $\leq 16\text{‰}$  for wheat,  $\leq 15.5\text{‰}$  for lentil and  $\leq 17\text{‰}$  for barley as poorly watered, while intermediate values suggest moderate water availability (Wallace *et al.* 2013, 17 fig. 5).

$\delta^{15}\text{N}$  values are higher for  $\text{C}_4$  than  $\text{C}_3$  plants and, in both, increase with aridity (Hartman & Danin 2010). Addition of organic nitrogen, especially animal manure, increases  $\delta^{15}\text{N}$  in *cereals* (Bogaard *et al.* 2007; 2013; 2016; Bol *et al.* 2005; Fraser *et al.* 2011; Kanstrup *et al.* 2011;

2012). *Pulses* typically exhibit  $\delta^{15}\text{N}$  close to 0‰ (Virginia and Delwiche 1982), unless soil nitrogen concentration is high enough to inhibit fixation from air and favour assimilation from soil (Andrews *et al.* 2009; Ledgard *et al.* 1996; Peoples *et al.* 2009; Vinther 1998).

Experimentally-grown cereals in central-northwestern Europe have demonstrated  $\delta^{15}\text{N}$  values of >3‰ and >6‰ with moderate (15-20 t/ha) and high (30-35 t/ha) farmyard manure applications, respectively, while pulses show much smaller increases (~2‰) and only under extremely high applications (>70 t/ha) (Fraser *et al.* 2011; Treasure *et al.* 2016); equivalent ranges for (un)manured cereals are expected at the rainfall levels (~500 mm/year) around Knossos (cf. Styring *et al.* 2016b; 2017). In Greece, some pulses are manured very heavily for ease of cooking rather than high yields (Halstead 2014, 208).

Isotopic ratios may differ between grains from a single cereal ear by  $\leq 2.0\%$  in  $\delta^{15}\text{N}$  (Bogaard *et al.* 2007) and  $\leq 0.7\%$  in  $\delta^{13}\text{C}$  (Heaton *et al.* 2009), although within-pod variability in pulses is lower (Fraser *et al.* 2013; Treasure *et al.* 2016). Homogenizing multiple grains from the same field reduces variability (Kanstrup *et al.* 2012), with standard deviations for batches of 10 cereal or pulse grains of ~0.5‰ in  $\delta^{15}\text{N}$  and 0.25‰ in  $\delta^{13}\text{C}$  (Nitsch *et al.* 2015).

## S2. INTERPRETATION OF $\delta^{13}\text{C}$ AND $\delta^{15}\text{N}$ VALUES OF ANIMAL BONE COLLAGEN IN RELATION TO CHANGING LAND USE

Expectations regarding  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in animal bone collagen are complicated by trophic-level shifts between plant diet and animal tissue and by the diversity of plants potentially consumed. For ruminants of similar sizes to cattle, sheep and goats (cf. Tieszen 1991, 240), diet-bone collagen offsets have been suggested of ~5‰ in  $\delta^{13}\text{C}$  (Drucker *et al.* 2008, 72 table 2) and 3-5‰ in  $\delta^{15}\text{N}$  (Bocherens & Mariotti 2002, 1328-9 and table 2; Bocherens & Drucker 2007; Kendall *et al.* 2018, 140 table 2). For pigs a  $\delta^{13}\text{C}$  offset of 4‰ has been suggested (Froehle *et al.* 2010), while their omnivory may raise their  $\delta^{15}\text{N}$  values relative to the ruminants. For heuristic purposes, offsets of 5‰ for  $\delta^{13}\text{C}$  and an intermediate 4‰ for  $\delta^{15}\text{N}$  are adopted here for the ruminants, pig and also horse. These trophic-shift estimates are subject to variation and uncertainty (eg, Howland *et al.* 2003; Sponheimer *et al.* 2003; Caut *et al.* 2009; Makarewicz & Sealy 2015; Kendall *et al.* 2018; Codron *et al.* 2018), however, so only approximate values for average diet can be inferred from bone collagen measurements. To explore the degree of carnivory in Knossian dogs, we heuristically apply prey-predator offsets of ~1‰ in  $\delta^{13}\text{C}$  and

~4‰ in  $\delta^{15}\text{N}$ , based on data for temperate wolf and lynx with well documented prey composition (Bocherens & Drucker 2003, 48 tables 2-3; Fox-Dobbs *et al.* 2007, 463 table 2).

To address Knossian land use, the expected isotopic signal of livestock diet must be modelled by different routes for  $\text{C}_3$  forage (harvested fodder/grazed pasture) from cultivated land, for ‘rough’  $\text{C}_3$  pasture on uncultivated land, and for  $\text{C}_4$  forage.

### *C<sub>3</sub> forage from cultivated land*

Firstly, for  $\text{C}_3$  cereal and pulse *grain*, potentially subject to a great variety of husbandry regimes, measurements of specimens from Knossos itself (see below) provide locally relevant values and, although these are too sparse for phase-by-phase analysis, pooled Neolithic and pooled Bronze Age data offer some control over the effects of long-term changes in growing conditions on the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of crops potentially used as fodder. Secondly, using these data, approximate values can be estimated for fodder from  $\text{C}_3$  crop-cleaning by-products by subtracting from grain values 2.5‰ (chaff ~2‰ – Wallace *et al.* 2013; straw/leaf ~3‰ – Winkler *et al.* 1978, 259 table 2) for cereal  $\delta^{13}\text{C}$ , 1.5‰ (pod/straw/leaf – Treasure *et al.* 2016, 558 table 3) for pulse  $\delta^{13}\text{C}$ , 2.4‰ for cereal  $\delta^{15}\text{N}$  (chaff – Fraser *et al.* 2011, 2799) and 0.5‰ for pulse  $\delta^{15}\text{N}$  (pod/straw/leaf – Treasure *et al.* 2016, 558 table 3). Thirdly, livestock grazing harvested fields would have consumed a mix of fallen ears, crop stubble and weeds, with  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  thus intermediate between grain and straw/chaff, principally of cereals given that harvesting probably removed most of the pulse crop (Halstead 2014, 78-80). Animals grazing these fields during any ensuing fallow period (assuming dominance of non-leguminous weeds, especially after pulse crops and on manured land), or perhaps grazing early growth of cereals (potentially recovering to yield a grain crop) or poor crops not worth harvesting for grain (Halstead 2006, 50), should likewise have exhibited dietary values intermediate between ripe grain and straw/chaff of cereals in  $\delta^{13}\text{C}$  (Winkler *et al.* 1978, 259 table 2) and  $\delta^{15}\text{N}$  (eg, grain minus 1.4‰ – Styring *et al.* 2016b, 10).  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for stubble/fallow(/young cereal) graze (henceforth ‘stubble/fallow’) are estimated, therefore, as measured  $\text{C}_3$  cereal grain ranges minus 1.5‰ and 1.4‰, respectively. Fig. S1a-b shows, for Neolithic and Bronze Age Knossos respectively, the modelled  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  $\text{C}_3$  grain fodder,  $\text{C}_3$  chaff/straw fodder and cereal stubble/fallow pasture as confidence ellipses at one (68%) and two (95%) standard deviations. While livestock grazing across a range of stubble, fallow or crop fields are likely to

exhibit ‘averaged’  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values within the 68% ellipses, any animals largely foddered from, or pastured on, a particular cultivated plot may exhibit more extreme values outside this range.

#### *‘Rough’ $\text{C}_3$ pasture on uncultivated land*

Hartman and Danin (2010) analysed leaves of various plant life forms from protected sites over a 75-1000 mm/year mean annual rainfall gradient in the eastern Mediterranean, showing that, as expected, both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  $\text{C}_3$  plants decline with increasing rainfall (Hartman & Danin 2010, 845 fig. 4 and suppl. data). From these data (Hartman 2008, appx A), we constructed two regression models comparing the pooled wet- and dry-season  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for annuals/forbs and trees/shrubs (representing grazed and browsed rough pasture, respectively) against mean annual precipitation. From these models, we calculated  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values expected for annuals/forbs and trees/shrubs growing under 500 mm mean annual rainfall (comparable with the Knossos region over the last century), together with their upper and lower confidence intervals (Table S7); we excluded data for geophytes, as relatively uncommon, and dwarf shrubs, as relatively unpalatable to herbivores (Zohary & Orshan 1966, 17-18), and consider below the implications of assuming 600 mm rather than 500 mm rainfall (cf. Mauri *et al.* 2015).

Hartman and Danin sampled plants in summer 2006 and spring 2007, thus with estimated atmospheric  $\delta^{13}\text{C}$  values of -8.2‰, 1.8‰ lower than the 7<sup>th</sup>-2<sup>nd</sup> millennia BCE mean of -6.4‰ (range -6.7 to -6.3‰) (Indermühle *et al.* 1999; Ferrio *et al.* 2005; [http://web.udl.es/usuaris/x3845331/AIRCO2\\_LOESS.xls](http://web.udl.es/usuaris/x3845331/AIRCO2_LOESS.xls) downloaded 14-6-20). Because we compare these modern plant values with ancient faunal samples dated with variable precision, we allow for changing atmospheric  $\delta^{13}\text{C}$  values not by converting to  $\Delta^{13}\text{C}$ , but by adding 1.8‰ to 2006-7 values (Table S7). Fig. S1 shows the modelled  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of grazed and browsed lowland rough pasture as ellipses only at a 95% confidence level, because the baseline stable isotope data are derived from single measurements per life form, season and highly localised (10 m radius – Hartman 2008, 23) sampling site and so inevitably understate the variability of each pasture type.

Based on the lowland rough graze and browse ellipses, we model two further types of uncultivated forage (Fig. S1), not represented in the Hartman and Danin study: summer grazing

at high altitude, traditionally exploited on Crete by seasonally mobile herds of goats and especially sheep; and autumn-winter pannage (acorns, etc.) in low-altitude woodland, widely exploited across the Mediterranean to fatten small livestock, especially pigs (Parsons 1962; Albarella *et al.* 2007, 303; Hadjikoumis 2012, 359; Halstead & Isaakidou 2011, 166).

Relative to lowland rough graze,  $\delta^{13}\text{C}$  values of highland annuals and forbs should be depressed 1-2‰ by higher rainfall (eg, 1100 mm/yr for Anogia, at *c.* 740 m asl below Mt. Psiloritis – Tsiros *et al.* 2020), raised 1-2‰ by growth during summer (Hartman & Danin 2010, 845 fig. 4), and raised ~1‰ per 1000 m altitude by falling atmospheric pressure (Körner *et al.* 1988, 628 fig. 2b; 1991). Rough graze at 1000-2000 m on the Psiloritis or Lasithi mountains should thus have  $\delta^{13}\text{C}$  values ~1-2‰ higher than in the central lowlands, while east Mediterranean (Hartman & Danin 2010, 845 fig. 4a-b) and global (Handley *et al.* 1999, 192 fig. 1b) data suggest that higher precipitation should depress  $\delta^{15}\text{N}$  values by 1-2‰.

We model pannage on lowland Crete, using local rough browse as a baseline and west Mediterranean data for the offset between oak leaves (browse) and acorns (pannage). Average  $\delta^{13}\text{C}$  values of mature deciduous and evergreen oak leaves from open woodland in central Italy (Valentini *et al.* 1992) and southern France (Damesin *et al.* 1997), adjusted for sampling date (1990 and 1993) and higher mean annual rainfall (~900 mm), match the age-corrected dry-season mean for east Mediterranean shrubs/trees at 500 mm rainfall of ~-24‰ (Hartman 2008, appx A).  $\delta^{13}\text{C}$  values of *shelled* acorns (as pigs consume them – Zeman *et al.* 2016, 581) of deciduous and evergreen oaks from southern Spain (González-Martin *et al.* 1999) and evergreen oaks from southern Portugal (Alegria *et al.* 2020), again adjusted for sampling date (?1997 and 2017, respectively) and mean annual rainfall (~500-550 mm – <https://www.ipma.pt/pt/oclima/normais.clima/1971-2000/normalclimate7100.jsp>, consulted 21-8-20), are ~-20 and -21‰, respectively. This implies a 3‰ offset in  $\delta^{13}\text{C}$  values from browse to pannage for lowland central Crete, while a mean 2‰ offset in  $\delta^{15}\text{N}$  values is suggested by Portuguese evergreen oak data (Alegria *et al.* 2020).

#### *C<sub>4</sub> forage*

Knossian livestock potentially consumed  $\text{C}_4$  plants as cultivated fodder or rough pasture. Common millet and tiger nut were *possibly* cultivated, and used as fodder, on palatial-era Crete, but neither is represented in macroscopic archaeobotanical assemblages and thus available for

analysis. Fig. S1 therefore displays 68% and 95% confidence ellipses for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of common millet of similar date to palatial Knossos from Archontiko and Toumba Thessalonikis (Nitsch *et al.* 2017, 116-17 figs 4-5), in an area of northern Greece with similar modern annual rainfall (~450 mm) to lowland central Crete (Tsiros *et al.* 2020). For tiger nut,  $\delta^{13}\text{C}$  values of modern leaves from eastern North America (-12.7 and -11.1‰ – Li *et al.* 1999, 211 table 1) would, if age-corrected (collection dates not reported), approximate to those plotted for millet.  $\text{C}_4$ -rich or saline coastal rough pasture should also exhibit  $\delta^{13}\text{C}$  values comfortably higher than  $\text{C}_3$  vegetation (Farquhar *et al.* 1989, 520). In the east Mediterranean study,  $\text{C}_4$  plants were scarce above 350 mm annual rainfall, but available  $\delta^{13}\text{C}$  values are unrelated to rainfall, suggesting an ‘age-corrected’ range of ~-13 to -10‰ (Hartman & Danin 2010, appx B) for Neolithic-Bronze Age lowland central Crete; a  $\delta^{15}\text{N}$  value of ~1‰ might tentatively be extrapolated from lower-rainfall sites (Hartman & Danin 2010, appx C), but higher values would be anticipated for saline coastal rough pasture (Heaton 1987). The plotted ellipses for millet (Fig. S1) may thus serve as an approximate guide to  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  $\text{C}_4$  cultivated fodder or saline rough pasture on central Crete.

#### *Overview of modelled forage values*

As expected, the clearest distinction among forage categories is between  $\text{C}_3$ - and  $\text{C}_4$ -dominated fodder/pasture (Fig. S1) with low and high  $\delta^{13}\text{C}$  values, respectively. Among  $\text{C}_3$  forage, rough pasture is distinguished fairly clearly, by lower  $\delta^{15}\text{N}$  values, from cultivated fodder or pasture on cultivated land; a similar distinction between  $\text{C}_4$  rough pasture and  $\text{C}_4$  forage from cultivated land is unlikely given expected raised  $\delta^{15}\text{N}$  values for the former in saline coastal environments. Among  $\text{C}_3$  forage on cultivated ground, cereal/pulse grain exhibits higher  $\delta^{15}\text{N}$  and especially higher  $\delta^{13}\text{C}$  values than chaff/straw, with stubble/fallow pasture intermediate. Among  $\text{C}_3$  rough pasture,  $\delta^{13}\text{C}$  distinguishes between lowland graze (low values), lowland browse/upland summer graze (intermediate), and lowland pannage (high), while  $\delta^{15}\text{N}$  separates pannage (high) from lowland graze/browse (intermediate) and upland graze (low).

### **S3. LABORATORY ANALYTICAL METHODS AND QUALITY CRITERIA: PLANT REMAINS**

Visual inspection under a microscope showed no signs of surface soil contamination, and lack of contamination was confirmed by Fourier transform infrared spectroscopy (FTIR), following

reference contamination comparisons for humic acids, carbonates and nitrates (Vaiglova *et al.* 2014). Accordingly, the samples were not pre-treated. Samples of *c.* 5 to 10 grains were homogenized in an agate mortar and pestle. The homogenized powders were weighed into tin capsules for IRMS analysis with  $\delta^{13}\text{C}$  values and  $\delta^{15}\text{N}$  values measured separately. An internal alanine standard was used to calculate raw isotopic ratios (Table S8). Raw  $\delta^{13}\text{C}$  values were two-point normalised to the VPDB scale using IAEA-C6 and IAEA-C7, while  $\delta^{15}\text{N}$  values were normalized to the AIR scale using Caffeine and IAEA-N2. Raw and normalised data are presented in Table S1.

Reported measurement uncertainties are the calculated combined uncertainty of the raw measurement and reference standards, after Kragten (1994). The average measurement uncertainty was  $\pm 0.07\text{‰}$  for  $\delta^{13}\text{C}$  values and  $\pm 0.35\text{‰}$  for  $\delta^{15}\text{N}$  values. Full details of the analytical conditions are reported in Table S8. Plant data reliability was assessed by comparing  $\delta^{15}\text{N}$  values to C:N ratios as per Szpak and Chiou (2020). There is no significant relationship between the  $\delta^{15}\text{N}$  values and C:N ratios (see Fig. S2). The  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values were also compared to reported values from other sites in the region and show similarities. Both results suggest that the samples' isotopic values are a representation of the original isotopic compositions of the plants.

For some analyses, plant  $\delta^{13}\text{C}$  values were converted to carbon discrimination values ( $\Delta^{13}\text{C}$  values) to allow for comparison with modern research, following Farquhar *et al.* (1982; 1989). The  $\delta^{13}\text{C}$  value of atmospheric  $\text{CO}_2$  was estimated using reference tables from Ferrio *et al.* (2005) based on the date range of the samples (Table S1). The plant isotope results cited in the text are also corrected for the minor effect of charring on  $\delta^{13}\text{C}$  values (by subtracting  $0.11\text{‰}$ ) and  $\delta^{15}\text{N}$  values (by subtracting  $0.31\text{‰}$ ) (Nitsch *et al.* 2015), except where otherwise indicated. Full results of the plant remains isotope analysis are reported in Table S1. All calculations were performed using the statistical programming language R (RStudio version 1.4.1717).

#### S4. SAMPLING PROTOCOL, LABORATORY ANALYTICAL METHODS AND QUALITY CRITERIA: FAUNAL REMAINS

##### *Sampling protocol*

In the context of the *AGRICURB* project, faunal isotopic analysis was undertaken not as a 'control' for human palaeodietary reconstruction, but to explore variability in the diets and hence management strategies of different animal species consumed at Knossos in successive phases of

the Neolithic and Bronze Age. Key research questions of *AGRICURB* included the scale of animal husbandry and its degree of integration with agriculture, and hence the extent to which livestock were associated with the cultivated or ‘natural’ landscape. Ideally, therefore, analysis would have targeted both domestic and ‘wild’ species, but the latter were largely restricted at Knossos to Bronze Age fallow deer, for which, as human introductions to the island of Crete, a free-range life-style must be demonstrated rather than assumed. Analysis has thus focussed mainly on the four common domesticates: cattle, sheep, goats and pigs.

Samples were selected for analysis on the following criteria:

1. presence of thick cortical bone, as this is less prone to diagenetic deterioration of collagen than more porous cancellous bone and is thus more likely to contain adequate amounts of well-preserved collagen for isotopic analysis; cortical bone turns over more slowly than cancellous bone and so offers an isotopic record of the animal’s diet in the long term (cf. Sealy *et al.* 1995); this criterion is met especially in the diaphysis of major weight-bearing limb elements and in the mandible;
2. presence also of a well-preserved epiphysis (in the case of limb bones) or teeth (in the case of a few mandibular specimens), as these are most securely identifiable to species and also provide information on age at death and thus enable exclusion of specimens from very young animals with  $\delta^{15}\text{N}$  values elevated by suckling (eg, Balasse & Tresset 2002);
3. avoidance of specimens worked into artefacts and of parts of specimens bearing butchery marks, pathological traces and key morphological or biometrical information on species, age, or sex;
4. derivation, as far as possible, from a single anatomical element, given that bone collagen turnover rates vary between elements of different size and structure (Rodière *et al.* 1996, 181);
5. derivation, as far as possible, from the same side of the body (and, if not possible, taking account of size, robusticity and morphological details), to avoid duplicate samples from the same individual.

Criteria 1-2 were met by all sampled specimens and criterion 3 by 97% of those that yielded usable results (99% if postcranial specimens of clearly adult robusticity are considered ‘fused’ – see below). As regards criteria 3-4, distal humerus was the most abundantly and well-preserved

body part and also bears numerous characteristics enabling discrimination even between morphologically similar taxa, such as sheep and goat (Boessneck *et al.* 1964) or fallow and red deer (Lister 1996). Distal humerus accounts for 73% of samples with usable results, other postcranial body parts for 18% and mandibles (1 Neolithic dog; otherwise Bronze Age sheep and goats, some included in a previous incremental multi-isotope analysis of their teeth – Isaakidou *et al.* 2019) for 9%. Other postcranial elements make up only 2% of samples with usable results for sheep and 5% for goat, but 28% for pig (less abundant), 60% for cattle (heavily fragmented) and 55% for dog, 75% for fallow deer and 100% for badger and horse (all scarce).

Distal humerus (and likewise proximal radius) fuses late in the first (sheep, goat, pig) or early in the second (cattle) year (Silver 1969), by which time the common domesticates in this study should have been weaned for at least a few months. The  $\delta^{15}\text{N}$  values of fused specimens of distal humerus (and other limb elements that fuse at a similar or greater age) and likewise of sheep and goat mandibles with erupting or worn second molar (Deniz & Payne 1982; Jones 2006) should thus no longer reflect a suckling diet (Table S2: ‘Weaning status’). Such specimens make up 83% of samples with usable results or, including indeterminate specimens for which size and/or robusticity indicates a subadult or adult, 89%. A further 8% of usable results, comprising specimens with fusing distal humerus (/proximal radius) or sheep/goat mandibles with first molar in wear but second molar unerupted, were probably also weaned well before death. Only 3% of usable results (comprising unfused distal humerus/proximal radius, sheep/goat mandibles with first molar unworn or just coming into wear, and specimens preserving no evidence of age) have been categorised as *potentially* still suckling at death and, in practice, age at death may have been underestimated for some or even all of the ostensibly young postcranial specimens if castration (to encourage weight gain) had delayed fusion. Only the two youngest goat mandibles, with erupting first molar implying an age perhaps around 3-4 months, can be attributed to animals likely to have died before or soon after weaning and these two specimens indeed yielded  $\delta^{15}\text{N}$  values apparently influenced by suckling (see main text).

### *Sample extraction*

After photographing selected specimens from different views, sections of cortical bone were sawn from the thickest part of the shaft with a Dremel rotary tool for smaller bones or a hacksaw for the larger cattle bones. Samples were extracted at Oxford or at the Knossos Research Centre

of the British School at Athens, where the Neolithic and Bronze Age assemblages, respectively are stored. We followed the standard practice of extracting pieces of 1-5 g. While a minimum of 1 g of dry bone is required to obtain an adequate quantity of collagen for isotopic analysis, 5 g was obtained where possible (ie depending on species and size of the original specimen), to allow for loss from surface cleaning, any laboratory errors, such as malfunction of measuring instruments, accidental loss, etc. The surfaces of the sawn samples were subsequently cleaned by abrasion prior to pounding in a mortar. All analytical stages from surface cleaning onwards were performed at the Research Laboratory for Archaeology and the History of Art (RLAHA) of the University of Oxford, following standard Laboratory protocols.

### *Collagen extraction*

Collagen extraction followed the Longin (1971) method modified as described by Richards and Hedges (1999). All samples were run on a SerCon 20-22 EA-GSL isotope mass spectrometer. An internal alanine standard ( $\delta^{13}\text{C}$  -26.91‰ and  $\delta^{15}\text{N}$  -1.63‰) was used to calculate raw isotopic ratios and correct for drift. Raw  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values were normalised to the VPDB and AIR scales using an internal standard of seal collagen (SEAL  $\delta^{15}\text{N}$  17.3±0.29‰,  $\delta^{13}\text{C}$  -13.3±0.11‰) and Caffeine-2 (U. Indiana  $\delta^{15}\text{N}$  1±0.2‰,  $\delta^{13}\text{C}$  -27.771±0.043‰). The reported measurement uncertainties are the calculated combined uncertainty of the raw measurement and reference standards (after Kragten 1994). Values of measured standards are reported in Table S8. The average measurement uncertainty for collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values was ±0.09‰ and ±0.2‰ respectively. All calculations were performed using RStudio (1.3.1073) and R (3.2.4). Full results of the stable carbon and nitrogen isotope analysis are reported in Table S2a (Neolithic) and S2b (Bronze Age).

### *Quality criteria*

Apart from specimens with no or poor collagen preservation, a number of measurements were excluded from the analysis, when collagen exhibited: (a) a C:N ratio outside the range of 2.9-3.6 (following DeNiro 1985), and/or (b) low yields of nitrogen and/or carbon (see Table S2a-b). For the latter, assemblage-specific minima were set at 50 µg (Neolithic) and 60 µg (Bronze Age) for nitrogen and 150 µg (Neolithic) and 200 µg (Bronze Age) for carbon. Three further Neolithic samples were excluded from analysis due to poor analytical conditions. The breakdown of

successful sample frequency by period and species is presented in Table S4 and discussed in the main text.

## S5. ANIMAL BONE COLLAGEN RESULTS: PHASE-BY-PHASE OUTLIERS

Outliers, representing  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  values exceeding interquartile range  $\times 1.5$  for each chronological phase, were defined for sheep (Fig. 7a-b), goat (Fig. 7c-d) and cattle (Fig. 7e-f), but not pig (Fig. 7g-h) or the less common animal species. The quality control measures adopted (Supplementary text S4) provide grounds for optimism that outliers are not ‘rogue’ results of poor sample preservation or laboratory error, but rather represent animals of atypical dietary history. As the following discussion shows, a dietary explanation is not intrinsically implausible for any of the outliers.

### *Sheep*

For Neolithic sheep, phase-by-phase outliers (Fig. S4a) extend only modestly beyond the 95% confidence ellipse, especially towards lower  $\delta^{13}\text{C}_{\text{diet}}$  or higher  $\delta^{15}\text{N}_{\text{diet}}$  and may represent animals reared during an unusually wet period or tethered (in the case of an EN outlier) on a heavily manured garden, respectively. For the Bronze Age (Fig. S5a), conversely, outliers extend the sheep  $\delta^{13}\text{C}_{\text{diet}}$  range mainly towards higher values, with the highest (-22.4‰) of FP date possibly reflecting some intake of  $\text{C}_4$  grain fodder or  $\text{C}_4$ -rich/saline coastal rough pasture (the associated  $\delta^{15}\text{N}_{\text{diet}}$  value of 2.5‰ is compatible with either). Interpreting individual cases is hazardous, however, because bone collagen data represent ‘averages’ of potentially considerable seasonal or lifetime variation. For example, two non-outlier FP mandibles (MUM75 and RR191: Fig. 7b, nos. 1-2), slaughtered in their second or third year and previously identified by incremental  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  analysis of tooth enamel as vertically transhumant in their first or first and second summers (Isaakidou *et al.* 2019, 50), fall within the modelled range for cultivated land and well outside that for upland summer grazing. Conversely, for FP mandible MUM72 (Fig. 7b, no. 3), incremental dental data exhibit increased  $\delta^{13}\text{C}$  values in *winter*, suggesting seasonal consumption of  $\text{C}_4$ -rich/saline coastal pasture or grain fodder, but the  $\delta^{13}\text{C}_{\text{diet}}$  value of the mandibular bone collagen suggests long-term diet dominated by lightly manured cultivated land and perhaps  $\text{C}_3$  rough pasture. The bone collagen and incremental dental enamel values for  $\delta^{13}\text{C}$  are of course not directly comparable: in addition to contrasting temporal resolution, the former largely reflect protein intake and the latter whole diet or energy consumption (Lee-Thorp *et al.* 1989, 588).

Nonetheless, the apparent divergences between the two datasets caution against overly detailed interpretation of bone collagen outliers.

### *Goat*

Outliers (Figs S4-S5) extend positively the  $\delta^{13}\text{C}$  range for Neolithic and Bronze Age and the  $\delta^{15}\text{N}$  range especially for Bronze Age Knossos goats. Two (NP) high- $\delta^{15}\text{N}_{\text{diet}}$  cases ( $\sim 4\text{‰}$ ) are mandibles of three-month old kids (with erupting first molars), probably enriched by suckling (cf. Balasse & Tresset 2002), but the most salient (PreP) outlier ( $\delta^{15}\text{N}_{\text{diet}} 5.5\text{‰}$ ;  $\delta^{13}\text{C}_{\text{diet}} -24.5\text{‰}$ ) suggests generously manured forage, perhaps including substantial  $\text{C}_3$  grain, and may represent a pampered ‘house-goat’. Strikingly high  $\delta^{13}\text{C}_{\text{diet}}$  outliers of FN ( $-21.8\text{‰}$ ;  $\delta^{15}\text{N}_{\text{diet}} 2.8\text{‰}$ ) and FP ( $-21.2\text{‰}$ ;  $\delta^{15}\text{N}_{\text{diet}} 2.1\text{‰}$ ) date may also represent animals reared intensively with (lightly manured)  $\text{C}_3$  grain supplements or smaller  $\text{C}_4$  grain rations (arguably implausible for FN) or grazing  $\text{C}_4$ -rich/saline coastal rough pasture. The difficulty of interpreting individual cases, however, is again highlighted by a non-outlier FP mandible (MUM73: Fig. 7b, no. 6). Slaughtered in its second or third year and identified by incremental dental  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  analysis as potentially foddered in at least its first year (Isaakidou *et al.* 2019, 50), bone collagen data place this animal among the goats consuming cultivated and/or rough lowland graze.

### *Cattle*

The three  $\delta^{15}\text{N}$  outliers (Fig. 6f) fall within the corresponding Neolithic or Bronze Age 95% ellipse, but the sole  $\delta^{13}\text{C}$  outlier (Fig. 6e), of NP date, has a high  $\delta^{13}\text{C}_{\text{diet}}$  associated with a fairly low  $\delta^{15}\text{N}_{\text{diet}}$  value. This combination argues against  $\text{C}_4$ -rich/saline coastal pasture or  $\text{C}_4$  grain fodder as the source of raised  $\delta^{13}\text{C}_{\text{diet}}$  and, by elimination, perhaps favours  $\text{C}_3$  grain fodder grown under extensive conditions (Fig. S5c), although a diet dominated by rough browse in an arid area or period cannot be excluded.

## S6. EVALUATION OF ASSUMPTIONS UNDERPINNING MODELLING OF LIVESTOCK DIET

For clarity,  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  ranges for different forage types have been modelled assuming mean annual rainfall of  $\sim 500$  mm and plant-bone collagen trophic-level shifts of  $5\text{‰}$  for  $\delta^{13}\text{C}$  values and  $4\text{‰}$  for  $\delta^{15}\text{N}$  values. The resulting dietary reconstructions are plausible in terms of livestock feeding preferences and Knossos’ changing size and regional status. Here we consider whether

alterations to these underpinning assumptions would yield contrasting, but equally plausible, reconstructions.

Pollen-based, continental-scale climatic models, as yet with scant *local* empirical support (Mauri *et al.* 2015), suggest mean rainfall generally closer to 600 mm for Neolithic-Bronze Age lowland central Crete. At 600 mm,  $\delta^{13}\text{C}$  ranges should be lower for east Mediterranean annuals, forbs and shrubs/trees by  $\sim 0.4$ ,  $0.1\text{-}0.2$  and  $0.4\text{-}0.6\text{‰}$ , respectively, and  $\delta^{15}\text{N}$  ranges by  $\sim 0.4$ ,  $0.4\text{-}0.5$  and  $1\text{‰}$  (Hartman & Danin 2010, 845 fig. 4). These adjustments, especially to  $\delta^{15}\text{N}$  values, would reinforce the association of Knossian livestock (as inferred for 500 mm rainfall) with stubble/fallow graze and, except for Bronze Age goats, their divorce from rough browse and graze.

For  $\delta^{13}\text{C}$  values, a  $6\text{‰}$  trophic-level shift would lower estimated dietary ranges by  $1\text{‰}$ .

Excluding outliers, this would mostly confirm (sheep, cattle and pigs) or strengthen (Neolithic goats) reliance on stubble-fallow graze, but would associate Bronze Age goats more with rough graze and less with browse, despite their preference for the latter and its probably greater local availability. Conversely, a  $4\text{‰}$  shift would raise  $\delta^{13}\text{C}_{\text{diet}}$  values by  $1\text{‰}$ , shifting Neolithic goats and Bronze Age sheep, cattle and pigs from stubble/fallow pasture towards reliance on  $\text{C}_3$  grain fodder. Routine foddering with grain does not match the generally gracile build especially of Knossos sheep (Isaakidou 2005), however, and would undermine interpretation of the highest  $\delta^{13}\text{C}$  outlier as an intensively reared 'house-goat'.

For  $\delta^{15}\text{N}$  values, a  $3\text{‰}$  shift would raise estimated dietary values by  $1\text{‰}$ , enhancing the association of all livestock with forage (including  $\text{C}_3$  grain) from well manured cultivated land, to a degree perhaps incompatible with FP archaeobotanical and textual indications of extensive cultivation, and largely divorcing all but some Bronze Age goats from rough browse.

Conversely, a  $5\text{‰}$  shift would lower estimated dietary values by  $1\text{‰}$ , increasing implied use of rough pasture without negating primary dependence on forage from cultivated land, perhaps especially stubble/fallow graze. In sum, adopting different values for mean rainfall or trophic-level shifts yields dietary reconstructions that either broadly mirror those outlined above or are less compatible with livestock feeding preferences and other known constraints.

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## SUPPLEMENTARY FIGURE CAPTIONS

Fig. S1. Modelled  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  ranges for forage categories available to animals consumed at (a) Neolithic and (b) Bronze Age Knossos: ellipses for cultivated forage at 68% and 95% confidence intervals based on values for ancient cereal and pulse grains from Knossos (Table 2); ellipses for uncultivated forage at a 95% confidence interval based on values for modern plants growing at 500 mm mean annual rainfall in the east Mediterranean (Table S7) with allowance of + 1.8‰ for changes in the  $\delta^{13}\text{C}$  value of atmospheric  $\text{CO}_2$  (after Ferrio *et al.* 2005)

Fig. S2. Scatterplot of Knossos plant  $\delta^{15}\text{N}$  values and C:N ratio

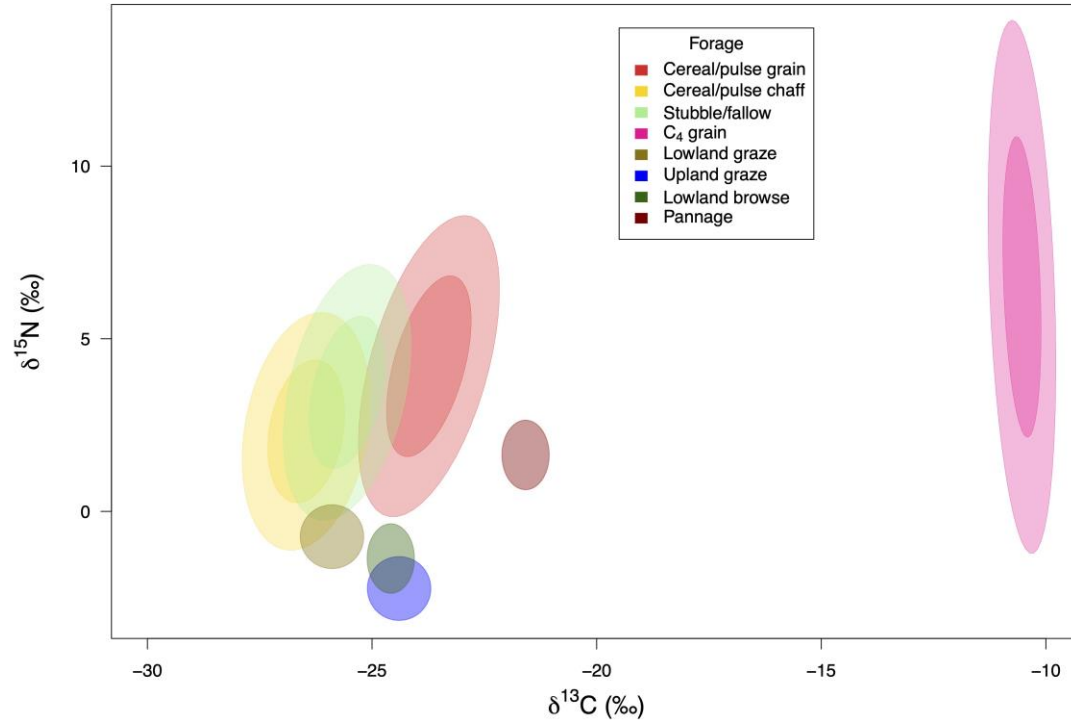
Fig. S3. Scatterplots of Knossos faunal bone collagen  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values by phase

Fig. S4.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values with 95% confidence ellipses, highlighting outliers (filled symbols) by phase, for a) sheep, b) goat, c) cattle and d) pig at Neolithic Knossos, compared with modelled forage categories (after Fig. S1a); bone collagen values adjusted for trophic level shifts of ~5‰ in  $\delta^{13}\text{C}$  and ~4‰ in  $\delta^{15}\text{N}$  values

Fig. S5.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values with 95% confidence ellipses, highlighting outliers (filled symbols) by phase, for a) sheep, b) goat, c) cattle and d) pig at Bronze Age Knossos, compared with modelled forage categories (after Fig. S1b); bone collagen values adjusted for trophic level shifts of ~5‰ in  $\delta^{13}\text{C}$  and ~4‰ in  $\delta^{15}\text{N}$  values

**Figure S1**

**a.**



S1b.

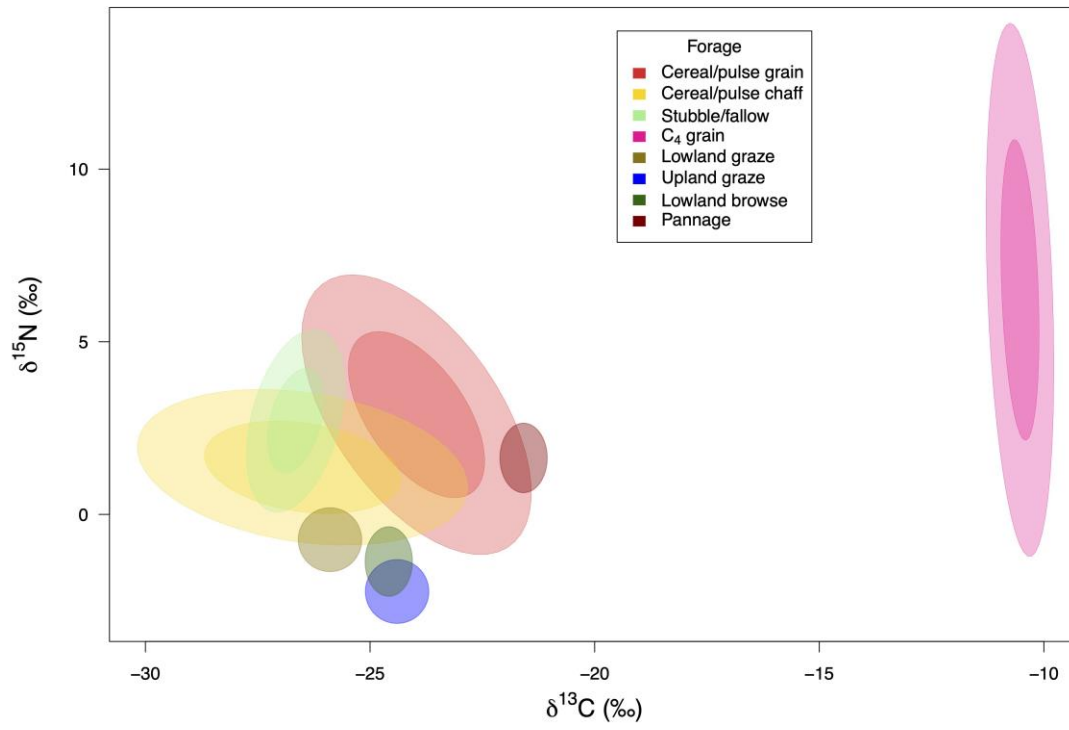


Figure S2

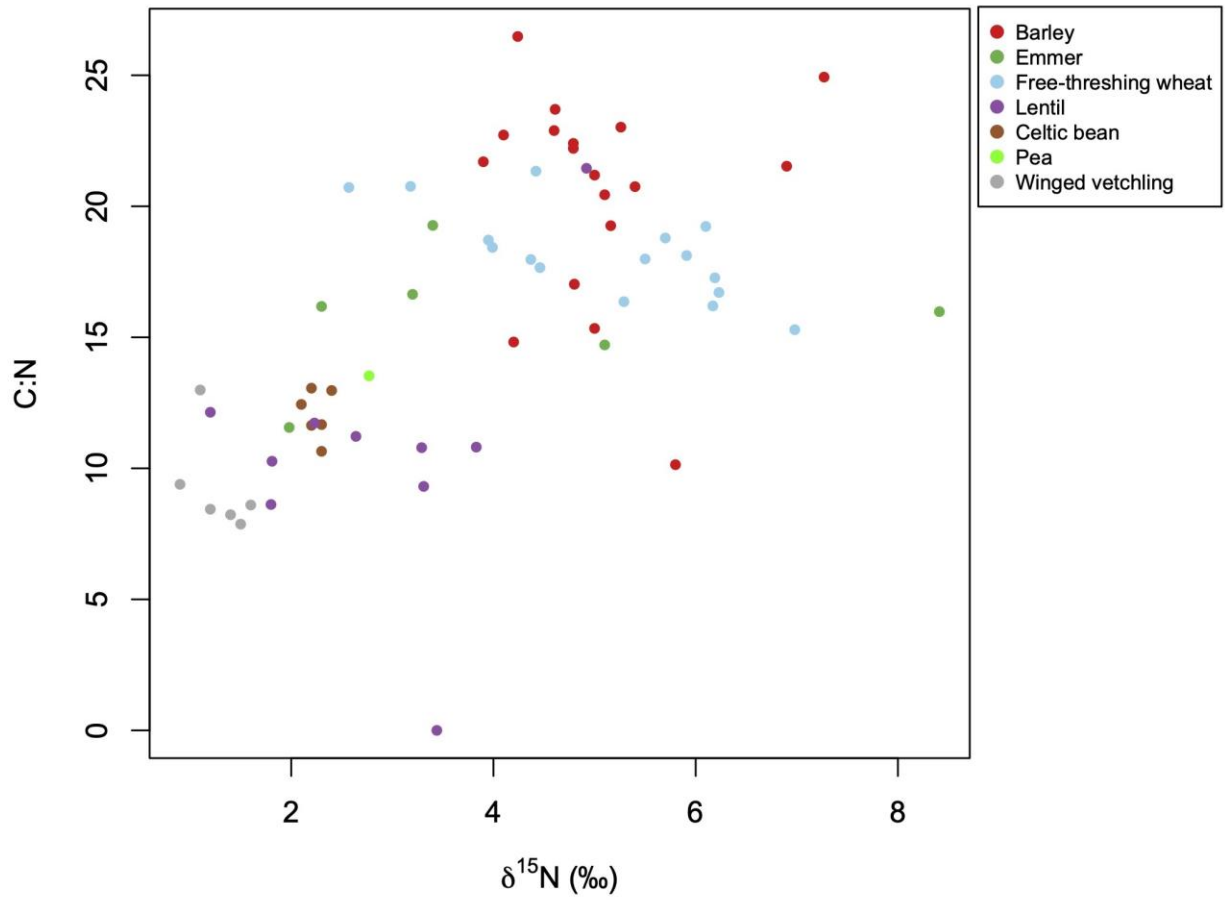


Figure S3

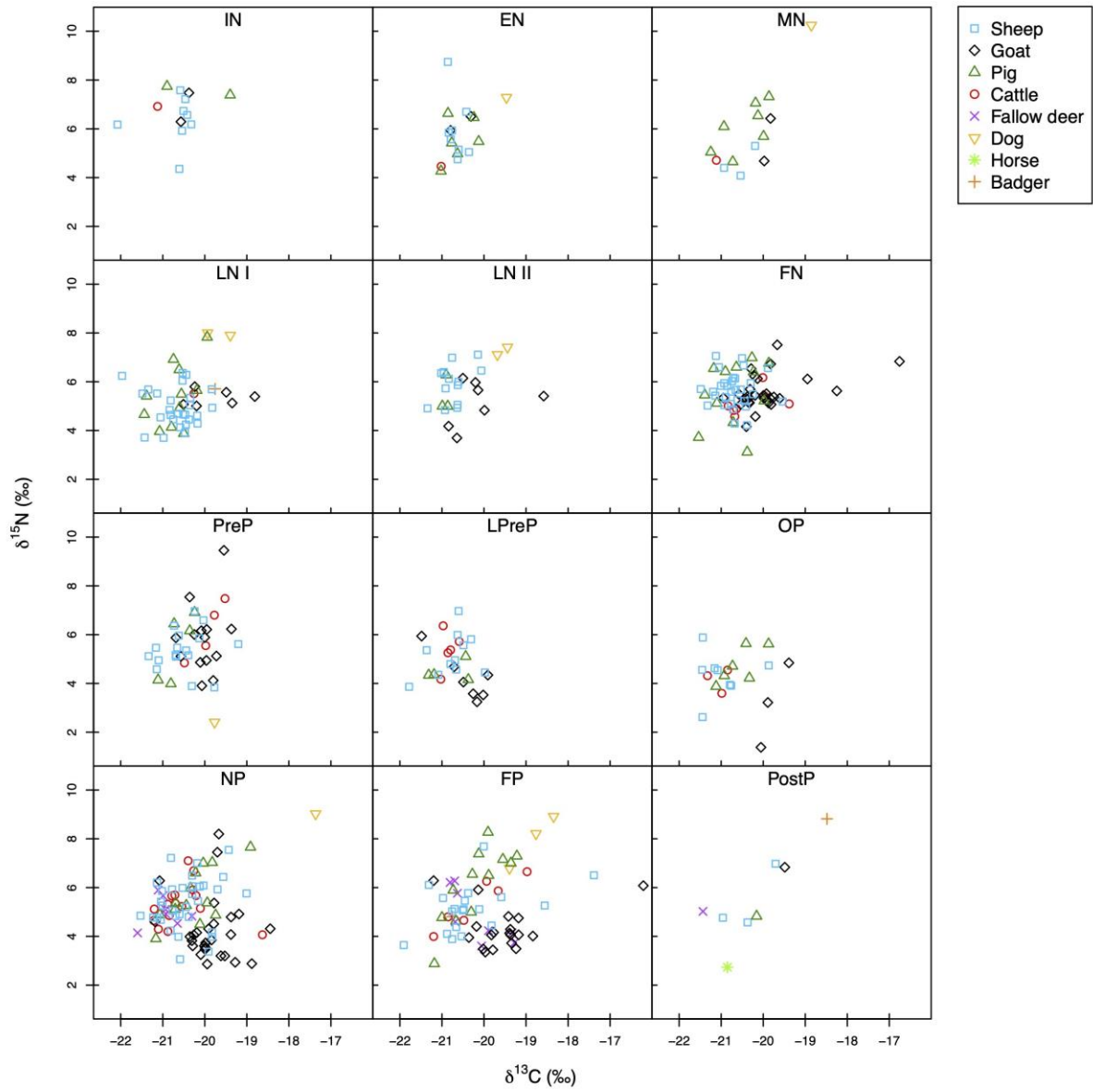


Figure S4

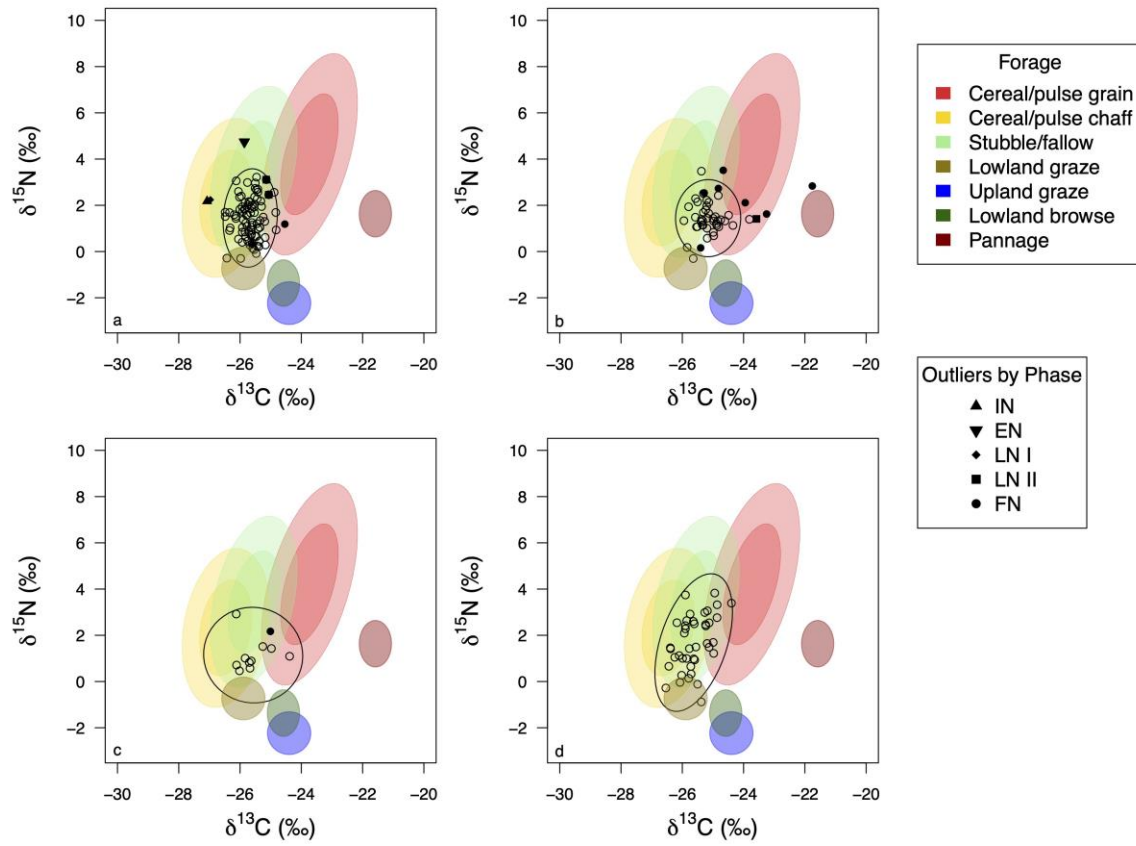


Figure S5

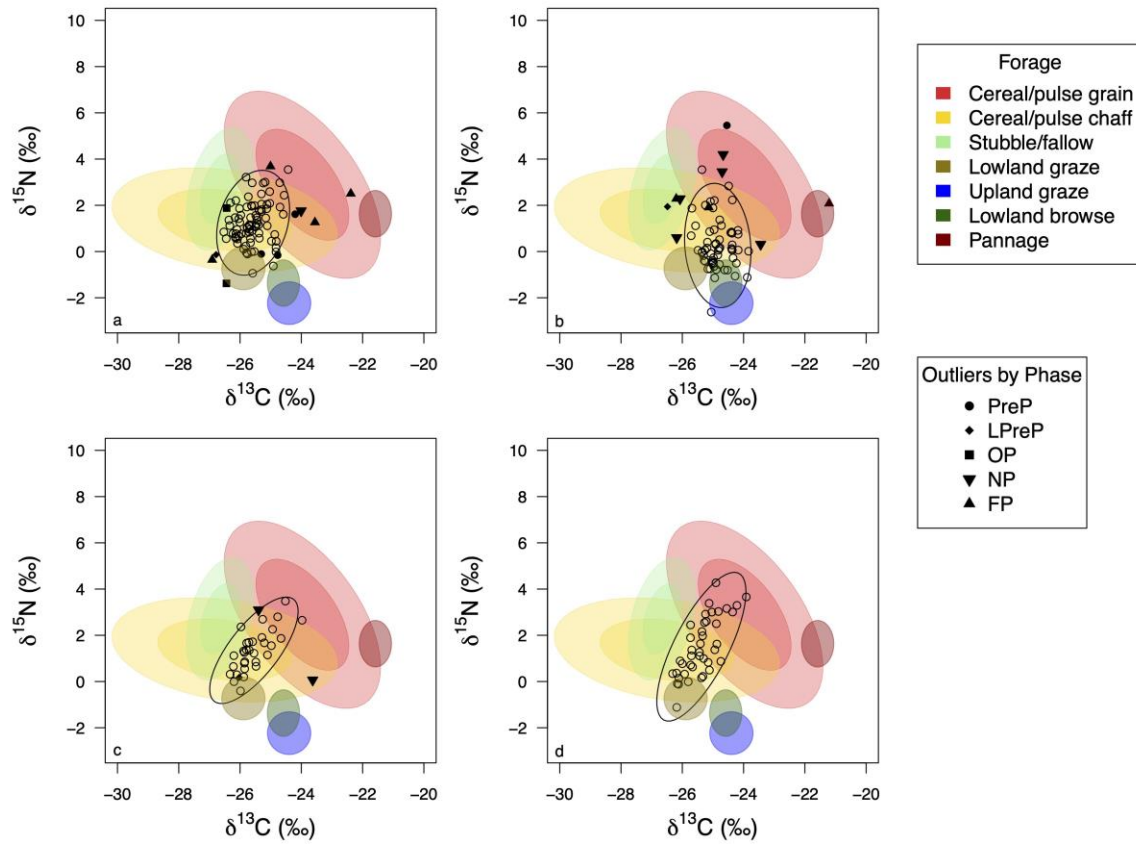


Table S1.  $\delta^{13}C$  and  $\delta^{15}N$  values of cereal and pulse grains from Neolithic and Bronze Age Knossos

AGRICURB ID	Excavation Sample No.	Room	Trench	Level	Date	Common name	Latin name	No. seeds	Runfile C	%C	$\delta^{13}C$ (-0.11‰ charring offset)										$\delta^{15}N$ (-0.31‰ charring offset)									
											$\delta^{13}C_{raw}$	$\delta^{13}C_{(PDB)}$	$\delta^{13}C_{sd}$	Runfile N	%N	$\delta^{15}N_{raw}$	$\delta^{15}N_{(AIR)}$	$\delta^{15}N_{sd}$	C/N	TPQ	TAQ	dair	$\Delta^{13}C$	Source for $\delta^{13}C$ values	Source for $\delta^{15}N$ values					
KNN001	n/a	n/a	AC	n/a	IN	Free-threshing wheat	Triticum aestivum/durum	10 150206B	49.65	-23.1	-23.4	-23.29	0.13	150324B	3.22	5.7	5.5	0.08	5.19	17.99	-6640	-6460	-6.48	17.4	Nitsch et al. 2019	Nitsch et al. 2019				
KNN002	n/a	n/a	AC	n/a	IN	Free-threshing wheat	Triticum aestivum/durum	10 150206B	49.2	-22.8	-23.2	-23.09	0.12	150324B	3.06	5.4	5.7	0.08	5.39	18.79	-6640	-6460	-6.48	17.1	Nitsch et al. 2019	Nitsch et al. 2019				
KNN003	n/a	n/a	AC	n/a	IN	Lentil	Lens culinaris	10 150207A	43.44	-22.7	-23.3	-23.19	0.63	150327B	5.88	1.6	1.8	0.24	1.49	8.62	-6640	-6460	-6.48	17.2	Nitsch et al. 2019	Nitsch et al. 2019				
KNN004	n/a	n/a	AC	n/a	IN	Free-threshing wheat	Triticum aestivum/durum	10 150207A	48.45	-22	-22.6	-22.49	0.63	150327B	2.94	5.9	6.1	0.23	5.79	19.23	-6640	-6460	-6.48	16.5	Nitsch et al. 2019	Nitsch et al. 2019				
KNK005	n/a	n/a	AA-BB	272	LN	Free-threshing wheat	Triticum aestivum/durum	6 151208	53.48	-23.08	-23.33	-23.22	0.09	151209B	3.39	4.26	3.99	0.32	3.68	18.43	-6000	-5300	-6.59	17.1	this paper	Styring et al. 2022				
KNK006	n/a	n/a	AA-BB	272	LN	Hulled barley	Hordeum vulgare	8 151208	63.01	-23.51	-23.76	-23.65	0.09	151209B	2.78	4.51	4.24	0.31	3.93	26.48	-6000	-5300	-6.59	17.6	this paper	Styring et al. 2022				
KNK007	n/a	n/a	AA-BB	272	LN	Lentil	Lens culinaris	5 151208	59.41	-24.10	-24.36	-24.25	0.09	151209B	5.71	1.48	1.20	0.34	0.89	12.14	-6000	-5300	-6.59	18.2	this paper	Styring et al. 2022				
KNK008	n/a	n/a	EE	8	FN	Lentil	Lens culinaris	9 151208	58.28	-23.56	-23.81	-23.70	0.09	151209B	6.29	4.10	3.83	0.32	3.52	10.81	-3600	-3300	-6.37	17.9	this paper	Styring et al. 2022				
KNK009	n/a	n/a	AA-BB	162	LN	Lentil	Lens culinaris	4 151208	57.91	-23.47	-23.72	-23.61	0.09	151209B	6.58	2.09	1.81	0.34	1.50	10.27	-4900	-4500	-6.29	17.9	this paper	Styring et al. 2022				
KNK010	n/a	n/a	AA-BB	279	LN	Free-threshing wheat	Triticum aestivum/durum	5 151208	58.70	-22.72	-22.96	-22.85	0.09	151209B	3.21	4.69	4.42	0.31	4.11	21.34	-6000	-5300	-6.59	16.8	this paper	Styring et al. 2022				
KNK011	n/a	n/a	AA-BB	279	LN	Free-threshing wheat	Triticum aestivum/durum	8 151208	61.61	-22.77	-23.01	-22.90	0.09	151209B	4.00	4.64	4.37	0.31	4.06	17.97	-6000	-5300	-6.59	16.8	this paper	Styring et al. 2022				
KNK012	n/a	n/a	AA-BB	251	LN	Lentil	Lens culinaris	4 151208	59.89	-24.80	-25.07	-24.96	0.09	151209B	5.96	2.51	2.23	0.33	1.92	11.73	-5300	-4900	-6.41	19.1	this paper	Styring et al. 2022				
KNK013	n/a	n/a	AA-BB	251	LN	Hulled barley	Hordeum vulgare	5 151208	58.04	-23.85	-24.11	-24.00	0.09	151209B	2.86	4.88	4.61	0.31	4.30	23.70	-5300	-4900	-6.41	18.1	this paper	Styring et al. 2022				
KNK014	n/a	n/a	AA-BB	251	LN	Free-threshing wheat	Triticum aestivum/durum	9 151208	61.20	-23.11	-23.36	-23.25	0.09	151209B	3.82	4.22	3.95	0.32	3.64	18.71	-5300	-4900	-6.41	17.4	this paper	Styring et al. 2022				
KNK015	n/a	n/a	X	19	IN	Lentil	Lens culinaris	5 151208	44.94	-23.86	-24.11	-24.00	0.09	151209B	5.63	3.58	3.31	0.32	3.00	9.31	-7000	-6400	-6.49	18.1	this paper	Styring et al. 2022				
KNK016	n/a	n/a	X	19	IN	Free-threshing wheat	Triticum aestivum/durum	5 151208	57.05	-22.83	-23.07	-22.96	0.09	151209B	4.11	6.43	6.17	0.30	5.86	16.20	-7000	-6400	-6.49	17.0	this paper	Styring et al. 2022				
KNK017	n/a	n/a	CC	50	FN	Hulled barley	Hordeum vulgare	5 151208	58.71	-23.11	-23.35	-23.24	0.09	151209B	3.38	7.16	6.90	0.29	6.59	21.53	-4200	-3600	-6.36	17.4	this paper	Styring et al. 2022				
KNK018	n/a	n/a	X	19	IN	Emmer	Triticum dicoccum	5 151208	57.66	-24.16	-24.42	-24.31	0.09	151209B	5.82	2.25	1.98	0.34	1.67	11.56	-7000	-6400	-6.49	18.4	this paper	Styring et al. 2022				
KNK019	n/a	n/a	X	22	IN	Lentil	Lens culinaris	8 151208	59.75	-23.98	-24.23	-24.12	0.09	151209B	3.25	5.19	4.92	0.31	4.61	21.45	-7000	-6400	-6.49	18.2	this paper	Styring et al. 2022				
KNK020	n/a	n/a	X	24	IN	Free-threshing wheat	Triticum aestivum/durum	6 151208	59.73	-23.05	-23.29	-23.18	0.09	151209B	4.56	7.24	6.98	0.29	6.67	15.29	-7000	-6400	-6.49	17.2	this paper	Styring et al. 2022				
KNK021	n/a	n/a	X	24	IN	Hulled barley	Hordeum vulgare	6 151208	59.96	-23.35	-23.60	-23.49	0.09	151209B	2.81	7.53	7.27	0.29	6.96	24.93	-7000	-6400	-6.49	17.5	this paper	Styring et al. 2022				
KNK022	n/a	n/a	X	24	IN	Lentil	Lens culinaris	16 151208	57.05	-23.34	-23.59	-23.48	0.09	151209B	6.17	3.56	3.29	0.32	2.98	10.79	-7000	-6400	-6.49	17.5	this paper	Styring et al. 2022				
KNK023	n/a	n/a	CC	51	FN	Hulled barley	Hordeum vulgare	6 151208	60.29	-22.83	-23.07	-22.96	0.09	151209B	3.27	5.06	4.79	0.31	4.48	22.21	-4200	-3900	-6.37	17.1	this paper	Styring et al. 2022				
KNK024	n/a	n/a	AA	37	FN	Pea	Pisum sp.	6 151208	63.00	-24.06	-24.32	-24.21	0.09	151209B	5.43	3.05	2.77	0.33	2.46	13.53	-4200	-3600	-6.36	18.4	this paper	Styring et al. 2022				
KNK025	n/a	n/a	CC	50	FN	Free-threshing wheat	Triticum aestivum/durum	7 151208	60.80	-23.18	-23.43	-23.32	0.09	151209B	4.17	5.07	4.80	0.31	4.49	17.01	-4200	-3600	-6.36	17.5	this paper	Styring et al. 2022				
KNK026	n/a	n/a	EE	22	FN	Lentil	Lens culinaris	11 151208	59.25	-24.42	-24.68	-24.57	0.09	151209B	6.16	2.91	2.64	0.33	2.33	11.22	-4500	-4200	-6.33	18.8	this paper	Styring et al. 2022				
KNK027	n/a	n/a	EE	27	FN	Lentil	Lens culinaris	7 151208	n/a	n/a	n/a	n/a	1.61	151209B	5.51	3.71	3.44	0.32	3.13	0.00	-4500	-4200	-6.33	n/a	this paper	Styring et al. 2022				
KNK028	n/a	n/a	EE	27	FN	Hulled barley	Hordeum vulgare	5 151208	62.29	-24.79	-25.06	-24.95	0.09	151209B	3.16	5.53	5.26	0.30	4.95	23.02	-4500	-4200	-6.33	19.2	this paper	Styring et al. 2022				
KNK029	n/a	n/a	EE	22	FN	Emmer	Triticum dicoccum	4 151208	60.87	-22.46	-22.70	-22.59	0.08	151209B	4.45	8.67	8.41	0.28	8.10	15.98	-4500	-4200	-6.33	16.7	this paper	Styring et al. 2022				
KNK030	n/a	n/a	EE	27	FN	Free-threshing wheat	Triticum aestivum/durum	9 151208	61.06	-23.41	-23.66	-23.55	0.09	151209B	4.03	4.73	4.46	0.31	4.15	17.66	-4500	-4200	-6.33	17.7	this paper	Styring et al. 2022				
KNK031	n/a	n/a	AA	37	FN	Free-threshing wheat	Triticum aestivum/durum	5 151208	58.98	-22.81	-23.06	-22.95	0.09	151209B	4.21	5.56	5.29	0.30	4.98	16.36	-4200	-3600	-6.36	17.1	this paper	Styring et al. 2022				
KNK032	n/a	n/a	AA	26	IN	Free-threshing wheat	Triticum aestivum/durum	5 151208	61.77	-22.45	-22.69	-22.58	0.08	151209B	4.17	6.46	6.19	0.29	5.88	17.27	-6640	-6460	-6.48	16.6	this paper	Styring et al. 2022				
KNK033	n/a	n/a	EE	22	FN	Free-threshing wheat	Triticum aestivum/durum	6 151208	60.55	-23.75	-24.00	-23.89	0.09	151209B	3.90	6.18	5.91	0.30	5.60	18.12	-4500	-4200	-6.33	18.1	this paper	Styring et al. 2022				
KNK034	n/a	n/a	EE	8	FN	Free-threshing wheat	Triticum aestivum/durum	12 151208	60.60	-23.01	-23.25	-23.14	0.09	151209B	4.23	6.50	6.23	0.29	5.92	16.71	-3600	-3300	-6.37	17.3	this paper	Styring et al. 2022				
KNK035	n/a	n/a	AA-BB	246	LN	Free-threshing wheat	Triticum aestivum/durum	7 151208	62.23	-23.21	-23.46	-23.35	0.09	151209B	3.50	2.85	2.57	0.33	2.26	20.72	-5300	-4900	-6.41	17.5	this paper	Styring et al. 2022				
KNK036	n/a	n/a	AA-BB	246	LN	Hulled barley	Hordeum vulgare	5 151208	61.04	-23.84	-24.09	-23.98	0.09	151209B	3.70	5.42	5.16	0.30	4.85	19.26	-5300	-4900	-6.41	18.1	this paper	Styring et al. 2022				
KNK037	n/a	n/a	AA-BB	252	LN	Free-threshing wheat	Triticum aestivum/durum	9 151208	65.95	-23.29	-23.54	-23.43	0.09	151209B	3.71	3.45	3.18	0.32	2.87	20.76	-5300	-4900	-6.41	17.5	this paper	Styring et al. 2022				
KNK038	n/a	n/a	AA-BB	252	LN	Hulled barley	Hordeum vulgare	6 151208	61.26	-23.13	-23.37	-23.27	0.09	151209B	3.19	5.06	4.79	0.31	4.48	22.40	-5300	-4900	-6.41	17.4	this paper	Styring et al. 2022				
KNB001	1	Storeroom P	n/a	n/a	FP (LM II)	Emmer	Triticum dicoccum	10 150207A	48.37	-24.2	-24.9	-24.79	0.64	150324B	3.39	3.1	3.2	0.08	2.89	16.64	-1470	-1410	-6.46	18.9	Nitsch et al. 2019	Nitsch et al. 2019				
KNB002	1	Storeroom P	n/a	n/a	FP (LM II)	Emmer	Triticum dicoccum	10 150207A	47.92	-23.8	-24.4	-24.29	0.64	150324B	2.9	3.3	3.4	0.08	3.09	19.27	-1470	-1410	-6.46	18.4	Nitsch et al. 2019	Nitsch et al. 2019				
KNB003	1	Storeroom P	n/a	n/a	FP (LM II)	Emmer	Triticum dicoccum	10 150207A	47.7	-24	-24.6	-24.49	0.64	150324B	3.44	2.2	2.3	0.08	1.99	16.18	-1470	-1410	-6.46	18.7	Nitsch et al. 2019	Nitsch et al. 2019				
KNB004	5	Storeroom P	n/a	n/a	FP (LM II)	Hulled barley	Hordeum vulgare	5 150207A	50.34	-23.8	-24.4	-24.29	0.64	150324B	2.57	4.5	4.6	0.08	4.29	22.89	-1470	-1410	-6.46	18.4	Nitsch et al. 2019	Nitsch et al. 2019				
KNB005	5	Storeroom P	n/a	n/a	FP (LM II)	Hulled barley	Hordeum vulgare	5 150207A	48.51	-24.2	-24.8	-24.69	0.64	150324B	2.77	5	5.1	0.08	4.79	20.44	-1470	-1410	-6.46	18.8	Nitsch et al. 2019	Nitsch et al. 2019				
KNB006	5	Storeroom P	n/a	n/a	FP (LM II)	Hulled barley	Hordeum vulgare	5 150207A	49.24	-23.9	-24.5	-24.39	0.64	150324B	3.37	4.7	4.8	0.08	4.49	17.03	-1470	-1410	-6.46	18.5	Nitsch et al. 2019	Nitsch et al. 2019				
KNB007	5	Storeroom P	n/a	n/a	FP (LM II)	Hulled barley	Hordeum vulgare	5 150207A	50.1	-24.6	-25.2	-25.09	0.64	150324B	2.57	4	4.1	0.08	3.79	22.72	-1470	-1410	-6.46	19.2	Nitsch et al. 2019	Nitsch et al. 2019				
KNB008	7	Storeroom P	n/a	n/a	FP (LM II)	Winged vetchling	Lathyrus ochrus	5 150207A	47.31	-22.6	-23.2	-23.09	0.63	150324B	6.71	1.3	1.4	0.08	1.09	8.23	-1470	-1410	-6.46	17.2	Nitsch et al. 2019	Nitsch et al. 2019				
KNB009	7	Storeroom P	n/a	n/a	FP (LM II)	Winged vetchling	Lathyrus ochrus	5 150207A	49.52	-23	-23.6	-23.49	0.63	15																

Table S2a. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of animal bone collagen from Neolithic Knossos																		
Sample No	Phase	Species	Element	Weaning Status	C $\mu\text{g}$	%C	$\delta^{13}\text{C}_{(\text{raw})}$	$\delta^{13}\text{C}_{(\text{VPDB})}$	$\delta^{13}\text{C}$ sd	N $\mu\text{g}$	%N	$\delta^{15}\text{N}_{(\text{raw})}$	$\delta^{15}\text{N}_{(\text{AIR})}$	$\delta^{15}\text{N}$ sd	C:N	% Collagen Yield	Sample quality	Runfile
KN001	IN	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3.95	PCP	n/a
KN002	IN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3.65	PCP	n/a
KN003	IN	Sheep	Humerus	W	355.6	35.6	-20.4	-20.6	0.2	124.7	12.5	4.4	4.4	0.3	3.3	8.1	Good	150209A
KN004	IN	Sheep	Humerus	W	400.6	37.4	-20.4	-20.5	0.2	143.9	13.4	5.9	5.9	0.3	3.2	6.9	Good	150209A
KN005	IN	Sheep	Humerus	W	339.7	30.9	-21.9	-22.1	0.2	112.9	10.3	6.1	6.2	0.3	3.5	10.4	Good	150209A
KN006	IN	Sheep	Humerus	W	300.5	29.8	-20.4	-20.6	0.2	105.8	10.5	7.5	7.6	0.3	3.3	6.6	Good	150209A
KN007	IN	Sheep	Humerus	W	405.3	36.8	-20.3	-20.5	0.2	144.4	13.1	7.1	7.2	0.3	3.3	8.9	Good	150209A
KN008	IN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.10	PCP	n/a
KN009	IN	Sheep	Humerus	(U)	254.5	23.4	-20.3	-20.5	0.1	86.7	8.0	6.7	6.7	0.2	3.4	6.2	Good	150209B
KN010	IN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3.55	PCP	n/a
KN011	IN	Goat	Humerus	W	221.5	21.3	-20.2	-20.4	0.1	74.8	7.2	7.4	7.5	0.3	3.5	0.4	Good	150209B
KN012	EN	Goat	Humerus	W	399.3	38.0	-20.1	-20.3	0.1	140.8	13.4	6.5	6.5	0.2	3.3	12.2	Good	150209B
KN013	EN	Sheep	Humerus	W	393.2	34.8	-20.3	-20.4	0.1	139.3	12.3	6.7	6.7	0.2	3.3	10.7	Good	150209B
KN014	EN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.49	PCP	n/a
KN015	EN	Sheep	Humerus	W	303.6	29.8	-20.7	-20.9	0.1	107.2	10.5	8.7	8.7	0.3	3.3	7.7	Good	150209B
KN016	IN	Sheep	Humerus	W	280.8	26.7	-20.2	-20.3	0.1	96.9	9.2	6.2	6.2	0.2	3.4	7.3	Good	150209B
KN017	EN	Sheep	Humerus	W	274.6	26.9	-20.2	-20.4	0.1	94.3	9.2	5.1	5.0	0.2	3.4	6.3	Good	150209B
KN018	EN	Sheep	Humerus	W	304.1	29.8	-20.6	-20.8	0.1	106.3	10.4	5.6	5.6	0.2	3.3	8.2	Good	150209B
KN019	EN	Sheep	Humerus	W	275.4	24.6	-20.7	-20.8	0.1	94.3	8.4	5.8	5.8	0.2	3.4	6.2	Good	150209B
KN020	EN	Sheep	Humerus	(U)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5.58	PCP	n/a
KN021	EN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.55	PCP	n/a
KN022	EN	Sheep	Humerus	(U)	299.2	28.8	-20.6	-20.8	0.1	104.7	10.1	5.9	5.9	0.2	3.3	9.2	Good	150209B
KN023	EN	Goat	Humerus	(U)	343.7	31.2	-20.6	-20.8	0.1	120.9	11.0	5.9	5.9	0.2	3.3	8.1	Good	150209B
KN024	EN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.29	PCP	n/a
KN025	IN	Sheep	Humerus	W	201.2	18.3	-20.3	-20.4	0.1	67.1	6.1	6.5	6.6	0.2	3.5	5.8	Good	150209B
KN026	EN	Sheep	Humerus	W	399.8	34.8	-20.5	-20.6	0.1	141.0	12.3	4.8	4.8	0.2	3.3	6.1	Good	150209B
KN027	EN	Sheep	Metacarpal	W	304.0	30.7	-20.6	-20.6	0.1	109.3	11.0	5.1	5.1	0.2	3.2	8.3	Good	151019C
KN028	MN	Sheep	Metacarpal	W	373.7	34.0	-20.2	-20.2	0.1	131.4	11.9	5.2	5.3	0.2	3.3	4.5	Good	151019C
KN029	MN	Sheep	Metacarpal	(W)	224.2	19.5	-20.9	-20.9	0.1	78.5	6.8	4.3	4.4	0.2	3.3	3.9	Good	151019C
KN030	IN	Goat	Tibia	W	460.6	41.9	-20.6	-20.6	0.1	167.5	15.2	6.2	6.3	0.2	3.2	8.5	Good	151019C
KN031	LN II	Goat	Humerus	W	137.7	12.2	-21.4	-21.4	0.1	44.3	3.9	5.3	5.4	0.2	3.6	0.6	High C:N	151019C
KN032	LN II	Goat	Humerus	W	138.7	12.0	-20.4	-20.4	0.1	47.6	4.1	5.0	5.1	0.2	3.4	2.9	Low N and/or C $\mu\text{g}$	151019C
KN033	LN II	Goat	Humerus	W	434.4	38.1	-18.6	-18.6	0.1	152.4	13.4	5.3	5.4	0.2	3.3	0.7	Good	151019C
KN034	LN II	Goat	Humerus	W	411.0	40.7	-20.2	-20.2	0.1	147.4	14.6	5.9	6.0	0.2	3.3	5.0	Good	151019C
KN035	LN II	Goat	Humerus	W	415.0	41.1	-20.0	-20.0	0.1	143.5	14.2	4.7	4.8	0.2	3.4	1.2	Good	151019C
KN036	LN II	Goat	Humerus	W	468.8	42.6	-20.8	-20.8	0.1	162.4	14.8	4.1	4.2	0.2	3.4	0.3	Good	151019C
KN037	LN II	Goat	Humerus	W	386.5	38.6	-20.7	-20.6	0.1	132.7	13.3	3.6	3.7	0.2	3.4	0.3	Good	151019C
KN038	LN II	Goat	Humerus	W	40.1	3.6	-20.7	-20.7	0.1	13.2	1.2	5.3	5.4	0.2	3.5	2.4	Low N and/or C $\mu\text{g}$	151019C
KN039	LN II	Goat	Humerus	W	191.3	18.0	-20.5	-20.5	0.1	66.0	6.2	6.1	6.1	0.2	3.4	2.3	Good	151019C

KN040	LN I	Sheep	Humerus	W	390.6	36.5	-20.2	-20.2	0.1	141.2	13.2	4.5	4.6	0.2	3.2	10.9	Good	151019C
KN041	LN I	Sheep	Humerus	W	229.1	21.0	-21.3	-21.3	0.1	80.5	7.4	5.6	5.7	0.2	3.3	3.8	Good	151019C
KN042	LN I	Sheep	Humerus	W	256.5	22.7	-20.5	-20.5	0.1	91.1	8.1	6.0	6.0	0.2	3.3	6.0	Good	151019C
KN043	LN I	Sheep	Humerus	W	377.8	36.3	-20.4	-20.3	0.1	136.0	13.1	5.3	5.3	0.2	3.2	12.5	Good	151019C
KN044	LN I	Sheep	Humerus	W	487.2	42.4	-20.6	-20.6	0.1	175.6	15.3	4.6	4.7	0.2	3.2	11.2	Good	151019C
KN045	LN I	Sheep	Humerus	W	412.8	39.3	-20.5	-20.5	0.1	148.7	14.2	6.3	6.4	0.2	3.2	8.5	Good	151019C
KN046	LN I	Sheep	Humerus	W	404.1	39.2	-21.4	-21.4	0.1	145.4	14.1	3.6	3.7	0.2	3.2	1.7	Good	151019C
KN047	LN I	Sheep	Humerus	W	366.4	32.1	-19.9	-19.8	0.1	132.1	11.6	5.6	5.7	0.2	3.2	11.5	Good	151019C
KN048	LN I	Sheep	Humerus	W	408.7	37.8	-20.8	-20.8	0.1	146.5	13.6	4.8	4.8	0.2	3.3	2.5	Good	151019C
KN049	LN I	Sheep	Humerus	W	255.0	25.0	-21.1	-21.0	0.1	90.7	8.9	3.7	3.7	0.2	3.3	4.7	Good	151020A
KN050	LN I	Sheep	Humerus	W	463.9	41.8	-20.5	-20.4	0.1	167.7	15.1	4.5	4.5	0.2	3.2	11.0	Good	151020A
KN051	LN I	Sheep	Humerus	W	387.9	37.3	-20.9	-20.8	0.1	137.7	13.2	5.3	5.2	0.2	3.3	1.2	Good	151020A
KN052	LN I	Sheep	Humerus	W	430.1	40.6	-20.9	-20.8	0.1	154.5	14.6	4.7	4.6	0.2	3.2	4.0	Good	151020A
KN053	LN I	Sheep	Humerus	W	429.1	42.1	-20.7	-20.6	0.1	145.4	14.3	4.1	4.1	0.2	3.4	0.6	Good	151020A
KN054	LN I	Sheep	Humerus	W	265.0	26.2	-20.9	-20.7	0.1	93.8	9.3	4.5	4.5	0.2	3.3	8.9	Good	151020A
KN055	LN I	Sheep	Humerus	W	198.0	17.4	-20.8	-20.7	0.1	68.8	6.0	5.2	5.2	0.2	3.4	2.8	Low N and/or C µg	151020A
KN056	LN I	Sheep	Humerus	W	139.7	13.6	-21.0	-21.0	0.1	48.9	4.7	4.7	4.7	0.2	3.3	3.9	Low N and/or C µg	151020A
KN057	LN I	Sheep	Humerus	W	433.3	42.1	-19.9	-19.8	0.1	156.7	15.2	5.0	4.9	0.2	3.2	7.6	Good	151020A
KN058	LN I	Sheep	Humerus	W	273.2	24.6	-22.1	-22.0	0.1	95.2	8.6	6.3	6.2	0.2	3.3	2.9	Good	151020A
KN059	LN I	Sheep	Humerus	W	431.4	41.1	-20.5	-20.4	0.1	155.6	14.8	5.1	5.0	0.2	3.2	5.0	Good	151020A
KN060	LN I	Sheep	Humerus	W	21.8	2.1	-21.9	-21.8	0.1	6.2	0.6	4.4	4.4	0.2	4.1	0.6	High C:N	151020A
KN061	LN I	Sheep	Humerus	W	237.5	22.6	-21.6	-21.5	0.1	83.7	8.0	5.5	5.5	0.2	3.3	1.8	Good	151020A
KN062	LN I	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.95	PCP	n/a
KN063	LN I	Sheep	Humerus	(U)	123.2	11.0	-21.2	-21.1	0.1	43.0	3.8	5.3	5.3	0.2	3.3	4.0	Low N and/or C µg	151020A
KN064	LN I	Sheep	Humerus	W	202.5	19.7	-21.2	-21.1	0.1	70.9	6.9	5.5	5.5	0.2	3.3	6.5	Good	151020A
KN065	LN I	Sheep	Humerus	W	418.0	37.7	-20.3	-20.2	0.1	151.6	13.7	4.3	4.3	0.2	3.2	10.3	Good	151020A
KN066	LN II	Sheep	Humerus	W	253.6	24.2	-21.0	-20.9	0.1	89.7	8.5	4.9	4.8	0.2	3.3	3.6	Good	151020A
KN067	LN I	Sheep	Humerus	W	189.3	16.9	-20.6	-20.5	0.1	66.7	6.0	3.9	3.9	0.2	3.3	3.8	Good	151020A
KN068	LN I	Sheep	Humerus	W	383.1	35.1	-21.2	-21.1	0.1	138.2	12.7	4.6	4.5	0.2	3.2	9.8	Good	151020A
KN069	LN I	Goat	Humerus	W	224.5	21.4	-19.6	-19.5	0.1	79.2	7.5	5.6	5.6	0.2	3.3	8.4	Good	151020A
KN070	LN I	Goat	Humerus	W	336.9	32.4	-20.3	-20.2	0.1	120.4	11.6	5.0	5.0	0.2	3.3	10.5	Good	151020A
KN071	LN I	Goat	Humerus	W	385.9	37.5	-19.5	-19.3	0.1	138.0	13.4	5.1	5.1	0.2	3.3	2.7	Good	151020A
KN072	LN I	Goat	Humerus	W	258.7	24.6	-20.3	-20.2	0.1	89.7	8.5	5.8	5.8	0.2	3.4	1.7	Good	151020A
KN073	LN I	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.19	PCP	n/a
KN074	LN I	Goat	Humerus	W	346.0	34.3	-18.9	-18.8	0.1	124.8	12.4	5.4	5.4	0.2	3.2	8.4	Good	151020A
KN075	LN I	Goat	Humerus	W	416.6	40.1	-20.6	-20.5	0.1	141.8	13.6	5.1	5.1	0.2	3.4	0.7	Good	151020A
KN076	LN I	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN077	LN I	Goat	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN078	MN	Goat	Humerus	W	231.3	22.7	-20.1	-20.0	0.1	81.9	8.0	4.7	4.7	0.2	3.3	5.7	Good	151020A

KN079	MN	Goat	Humerus	W	314.4	30.5	-19.9	-19.8	0.1	112.9	11.0	6.5	6.4	0.2	3.2	8.6	Good	151020A
KN080	MN	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN081	LN I	Goat	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN082	MN	Goat	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN083	MN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN084	LN I	Sheep	Humerus	W	330.0	30.3	-20.5	-20.4	0.1	118.6	10.9	6.3	6.3	0.2	3.2	9.1	Good	151020A
KN085	LN I	Sheep	Humerus	W	259.2	22.9	-20.6	-20.4	0.1	92.6	8.2	4.3	4.2	0.2	3.3	6.1	Good	151020A
KN086	LN I	Sheep	Humerus	W	275.7	27.8	-20.6	-20.5	0.1	93.1	9.4	4.5	4.6	0.2	3.5	9.2	Good	151207B
KN087	LN I	Sheep	Humerus	W	294.8	27.8	-20.7	-20.5	0.1	101.6	9.6	4.5	4.7	0.2	3.4	9.2	Good	151207B
KN088	MN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.84	PCP	n/a
KN089	MN	Sheep	Humerus	W	249.7	24.0	-20.7	-20.5	0.1	84.0	8.1	3.9	4.1	0.2	3.5	2.4	Good	151207B
KN090	MN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.56	PCP	n/a
KN091	LN II	Goat	Humerus	W	218.4	22.1	-20.3	-20.1	0.1	76.6	7.7	5.7	5.7	0.2	3.3	2.0	Good	151020A
KN092	LN II	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.47	PCP	n/a
KN093	LN II	Sheep	Humerus	W	99.5	8.7	-21.3	-21.2	0.1	34.0	3.0	6.1	6.1	0.2	3.4	2.4	Low N and/or C µg	151020A
KN094	LN II	Sheep	Humerus	W	208.6	20.9	-20.9	-20.8	0.1	73.1	7.3	6.2	6.1	0.2	3.3	4.7	Good	151020A
KN095	LN II	Sheep	Humerus	W	76.6	7.1	-21.8	-21.8	0.1	25.2	2.3	7.0	6.9	0.2	3.6	2.0	Low N and/or C µg	151020A
KN096	LN II	Sheep	Humerus	W	139.7	12.4	-20.5	-20.4	0.1	48.8	4.3	7.4	7.4	0.2	3.3	3.9	Low N and/or C µg	151020A
KN097	LN II	Sheep	Humerus	W	207.0	19.7	-20.6	-20.6	0.1	73.7	7.0	5.7	5.9	0.2	3.3	4.2	Good	151020B
KN098	LN II	Sheep	Humerus	W	484.8	42.5	-20.7	-20.6	0.1	170.2	14.9	4.9	5.1	0.2	3.3	0.4	Good	151020B
KN099	LN II	Sheep	Humerus	W	115.6	11.3	-20.5	-20.4	0.1	33.4	3.3	4.2	4.3	0.2	4.0	2.7	High C:N	151207B
KN100	LN II	Sheep	Humerus	(U)	425.7	40.5	-20.1	-20.1	0.1	152.9	14.6	6.3	6.5	0.2	3.2	9.3	Good	151020B
KN101	LN II	Sheep	Humerus	W	316.0	31.9	-21.0	-21.0	0.1	111.7	11.3	6.3	6.4	0.2	3.3	4.6	Good	151020B
KN102	LN II	Sheep	Humerus	W	475.0	41.7	-20.8	-20.8	0.1	169.1	14.8	6.9	7.0	0.2	3.3	7.2	Good	151020B
KN103	LN II	Sheep	Humerus	W	297.8	27.8	-20.6	-20.6	0.1	106.3	9.9	5.9	6.0	0.2	3.3	14.0	Good	151020B
KN104	LN II	Sheep	Humerus	W	108.2	10.7	-20.8	-20.7	0.1	37.4	3.7	6.0	6.1	0.2	3.4	3.5	Low N and/or C µg	151020B
KN105	LN II	Sheep	Humerus	W	67.3	6.2	-21.0	-21.0	0.1	23.0	2.1	5.3	5.4	0.2	3.4	1.7	Low N and/or C µg	151020B
KN106	LN II	Sheep	Humerus	W	426.8	37.1	-20.9	-20.9	0.1	141.6	12.3	5.6	5.7	0.2	3.5	1.2	Good	151020B
KN107	LN II	Sheep	Humerus	W	400.1	39.2	-20.7	-20.6	0.1	141.7	13.9	4.8	4.9	0.2	3.3	8.5	Good	151020B
KN108	LN II	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.08	PCP	n/a
KN109	LN II	Sheep	Humerus	W	423.0	36.8	-21.0	-21.0	0.1	148.8	12.9	6.2	6.4	0.2	3.3	2.7	Good	151020B
KN110	LN II	Sheep	Humerus	W	372.5	35.5	-21.4	-21.3	0.1	129.1	12.3	4.8	4.9	0.2	3.4	1.6	Good	151020B
KN111	IN	Pig	Femur	W	371.4	36.1	-20.9	-20.9	0.1	132.6	12.9	7.7	7.7	0.2	3.3	7.0	Good	151020B
KN112	EN	Pig	Tibia	(W)	39.0	3.8	-24.5	-24.5	0.1	9.0	0.9	8.2	8.3	0.2	5.1	1.1	High C:N	151020B
KN113	EN	Pig	Radius	(W)	365.0	35.1	-20.3	-20.2	0.1	131.6	12.6	6.4	6.5	0.2	3.2	12.0	Good	151020B
KN114	EN	Pig	Metatarsal	(W)	245.2	22.7	-20.9	-20.9	0.1	86.1	8.0	6.5	6.6	0.2	3.3	1.7	Good	151020B
KN115	EN	Pig	Metapodial	W	411.9	37.4	-20.7	-20.6	0.1	145.9	13.3	4.9	5.0	0.2	3.3	2.5	Good	151020B
KN116	IN	Pig	Femur	?	812.9	74.6	-23.8	-23.8	0.1	310.2	28.5	2.2	2.4	0.2	3.1	10.2	BAE	151020B
KN117	IN	Pig	Ulna	(W)	272.2	26.4	-19.4	-19.4	0.1	96.0	9.3	7.3	7.4	0.2	3.3	3.2	Good	151020B
KN118	EN	Pig	Ulna	W	299.8	26.1	-20.8	-20.8	0.1	99.2	8.6	5.3	5.4	0.2	3.5	1.2	Good	151020B

KN119	EN	Pig	Tibia	W	391.0	38.0	-20.2	-20.1	0.1	140.8	13.7	5.4	5.5	0.2	3.2	8.2	Good	151020B
KN120	EN	Pig	Metacarpal	W	395.5	39.5	-21.0	-21.0	0.1	139.6	14.0	4.1	4.3	0.2	3.3	5.8	Good	151020B
KN121	MN	Pig	Humerus	W	261.5	23.4	-21.3	-21.2	0.1	93.2	8.3	4.9	5.0	0.2	3.3	3.2	Good	151020B
KN122	MN	Pig	Humerus	W	226.1	21.7	-20.0	-20.0	0.1	80.1	7.7	5.6	5.7	0.2	3.3	5.1	Good	151020B
KN123	MN	Pig	Humerus	W	264.8	25.7	-21.0	-20.9	0.1	94.3	9.2	6.0	6.1	0.2	3.3	6.8	Good	151020B
KN124	MN	Pig	Humerus (W)		454.6	40.2	-20.2	-20.1	0.1	161.1	14.3	6.4	6.5	0.2	3.3	3.7	Good	151020B
KN125	MN	Pig	Humerus (W)		398.9	35.9	-20.2	-20.2	0.1	142.9	12.9	7.0	7.1	0.2	3.3	5.4	Good	151020B
KN126	MN	Pig	Radius	W	468.5	43.0	-20.7	-20.7	0.1	168.9	15.5	4.5	4.7	0.2	3.2	7.3	Good	151020B
KN127	MN	Pig	Humerus (U)		254.9	22.0	-19.9	-19.9	0.1	88.8	7.7	7.2	7.3	0.2	3.3	2.9	Good	151020B
KN128	LN I	Pig	Humerus	W	308.4	29.9	-20.8	-20.7	0.1	109.5	10.6	6.8	6.9	0.2	3.3	3.1	Good	151020B
KN129	LN I	Pig	Humerus	W	355.7	34.5	-21.4	-21.4	0.1	127.0	12.3	5.3	5.4	0.2	3.3	8.4	Good	151020B
KN130	LN I	Pig	Humerus	W	292.5	26.6	-21.1	-21.1	0.1	103.7	9.4	3.8	4.0	0.2	3.3	6.7	Good	151020B
KN131	LN I	Pig	Humerus (U)		296.3	28.2	-20.6	-20.6	0.1	105.6	10.1	6.4	6.5	0.2	3.3	7.5	Good	151020B
KN132	LN I	Pig	Radius	W	151.0	14.5	-21.5	-21.4	0.1	53.1	5.1	4.5	4.7	0.2	3.3	5.2	Good	151020B
KN133	LN I	Pig	Radius	W	381.7	36.4	-20.7	-20.6	0.1	134.9	12.8	4.8	4.9	0.2	3.3	0.3	Good	151020C
KN134	LN I	Pig	Radius	U	417.6	36.0	-20.0	-19.9	0.1	150.7	13.0	7.8	7.8	0.2	3.2	8.8	Good	151020C
KN135	LN I	Pig	Tibia (W)		442.6	41.0	-20.9	-20.8	0.1	155.8	14.4	4.0	4.1	0.2	3.3	9.8	Good	151207B
KN136	LN I	Pig	Tibia	W	452.9	42.7	-20.3	-20.2	0.1	163.5	15.4	5.6	5.6	0.2	3.2	8.3	Good	151020C
KN137	LN I	Pig	Radius	W	239.6	22.0	-20.6	-20.5	0.1	80.0	7.3	3.7	3.9	0.2	3.5	3.9	Good	151207B
KN138	MN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN139	LN I	Pig	Humerus	W	105.2	10.5	-21.2	-21.1	0.1	36.3	3.6	7.2	7.3	0.2	3.4	4.2	Low N and/or C µg	151020C
KN140	LN II	Pig	Radius	W	221.5	20.9	-21.0	-21.0	0.1	77.7	7.3	4.9	5.0	0.2	3.3	0.3	Good	151020C
KN141	LN II	Sheep	Humerus	W	427.4	37.8	-20.2	-20.1	0.1	153.3	13.6	7.0	7.1	0.2	3.3	12.7	Good	151020C
KN142	LN II	Sheep	Humerus	W	104.0	9.4	-20.8	-20.8	0.1	35.7	3.2	6.3	6.4	0.2	3.4	2.6	Low N and/or C µg	151020C
KN143	LN II	Sheep	Humerus	W	144.1	14.0	-20.3	-20.2	0.1	50.8	4.9	5.6	5.7	0.2	3.3	3.2	Low N and/or C µg	151020C
KN144	LN II	Pig	Humerus	W	19.8	1.8	-21.9	-21.8	0.1	5.3	0.5	1.3	1.4	0.2	4.4	1.5	High C:N	151207B
KN145	LN II	Pig	Humerus	W	114.2	10.8	-21.3	-21.2	0.1	32.9	3.1	2.2	2.3	0.2	4.0	4.7	High C:N	151207B
KN146	LN II	Pig	Radius	W	31.9	2.9	-21.9	-21.9	0.1	9.5	0.9	4.0	4.1	0.2	3.9	0.6	High C:N	151020C
KN147	LN II	Pig	Radius	W	415.4	37.4	-21.0	-20.9	0.1	142.2	12.8	6.2	6.3	0.2	3.4	-2.6	Good	151020C
KN148	LN I	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN149	LN I	Pig	Humerus	W	119.5	10.6	-21.2	-21.1	0.1	41.9	3.7	5.1	5.2	0.2	3.3	1.5	Low N and/or C µg	151020C
KN150	LN I	Pig	Humerus	W	248.0	22.3	-20.6	-20.6	0.1	86.2	7.8	5.4	5.5	0.2	3.4	2.9	Good	151020C
KN151	LN II	Pig	Humerus	W	77.2	6.9	-21.3	-21.2	0.1	26.9	2.4	7.5	7.6	0.2	3.3	4.4	Low N and/or C µg	151020C
KN152	LN II	Pig	Humerus	W	138.2	12.6	-21.5	-21.4	0.1	45.5	4.1	6.1	6.2	0.2	3.5	4.3	Low N and/or C µg	151020C
KN153	LN II	Pig	Humerus (U)		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN154	LN II	Pig	Humerus	W	111.0	10.9	-21.0	-20.9	0.1	38.2	3.7	5.0	5.1	0.2	3.4	2.1	Low N and/or C µg	151020C
KN155	LN II	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN156	FN	Pig	Humerus	W	102.7	9.3	-20.9	-20.9	0.1	35.3	3.2	4.5	4.6	0.2	3.4	2.1	Low N and/or C µg	151020C
KN157	FN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN158	FN	Pig	Humerus	W	11.8	1.1	-23.4	-23.4	0.1	3.2	0.3	4.4	4.5	0.2	4.3	2.6	High C:N	151020C

KN159	FN	Pig	Humerus	W	57.9	5.3	-22.0	-22.0	0.1	18.0	1.6	4.7	4.8	0.2	3.7	3.1	High C:N	151020C
KN160	FN	Pig	Humerus	W	99.5	9.0	-20.4	-20.3	0.1	33.7	3.1	7.7	7.8	0.2	3.4	3.8	Low N and/or C µg	151020C
KN161	FN	Pig	Humerus	W	70.6	6.8	-21.6	-21.5	0.1	23.9	2.3	4.3	4.4	0.2	3.4	2.0	Low N and/or C µg	151020C
KN162	FN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN163	FN	Pig	Humerus	W	300.6	27.3	-20.5	-20.4	0.1	102.4	9.3	3.0	3.1	0.2	3.4	3.9	Good	151207B
KN164	FN	Pig	Humerus	W	355.5	34.9	-20.3	-20.2	0.1	126.7	12.4	6.3	6.4	0.2	3.3	4.8	Good	151020C
KN165	FN	Pig	Humerus	W	423.1	39.9	-20.7	-20.6	0.1	149.3	14.1	6.5	6.6	0.2	3.3	2.0	Good	151020C
KN166	FN	Pig	Humerus	U	453.0	39.7	-21.4	-21.4	0.1	153.8	13.5	5.4	5.5	0.2	3.4	0.7	Good	151020C
KN167	FN	Pig	Humerus	(U)	59.3	5.7	-22.8	-22.8	0.1	17.6	1.7	6.1	6.2	0.2	3.9	1.1	High C:N	151020C
KN168	FN	Pig	Humerus	(U)	337.2	32.4	-21.2	-21.1	0.1	120.3	11.6	5.0	5.1	0.2	3.3	9.2	Good	151020C
KN169	LN II	Pig	Humerus	W	264.4	24.7	-20.9	-20.9	0.1	93.8	8.8	4.9	5.0	0.2	3.3	2.8	Good	151020C
KN170	FN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN171	FN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN172	FN	Pig	Humerus	W	418.7	38.1	-21.2	-21.2	0.1	138.6	12.6	6.5	6.5	0.2	3.5	-3.1	Good	151020C
KN173	FN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN174	FN	Pig	Humerus	(U)	410.1	39.4	-21.6	-21.5	0.1	140.3	13.5	3.6	3.7	0.2	3.4	0.5	Good	151020C
KN175	FN	Pig	Humerus	(U)	72.6	6.7	-21.4	-21.4	0.1	24.2	2.2	7.4	7.5	0.2	3.5	3.2	Low N and/or C µg	151020C
KN176	FN	Pig	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN177	FN	Pig	Humerus	(U)	428.8	38.3	-20.0	-20.0	0.1	150.7	13.5	5.1	5.2	0.2	3.3	1.2	Good	151020C
KN178	FN	Pig	Humerus	U	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN179	FN	Pig	Humerus	W	158.7	14.4	-19.9	-19.9	0.1	55.6	5.1	6.7	6.8	0.2	3.3	2.8	Good	151020C
KN180	FN	Pig	Humerus	(U)	37.2	3.4	-27.0	-27.0	0.1	4.4	0.4	4.5	4.6	0.2	9.9	0.5	High C:N	151020C
KN181	FN	Pig	Radius	W	233.7	22.5	-21.0	-20.9	0.1	82.1	7.9	6.3	6.4	0.2	3.3	4.1	Good	151020C
KN182	FN	Pig	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN183	FN	Pig	Radius	W	44.0	3.9	-23.3	-23.3	0.1	10.2	0.9	4.6	4.7	0.2	5.0	0.4	High C:N	151020C
KN184	FN	Pig	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN185	FN	Pig	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN186	FN	Pig	Radius	U	455.1	39.6	-20.3	-20.3	0.1	157.5	13.7	7.0	7.0	0.2	3.4	0.5	Good	151021A
KN187	FN	Goat	Humerus	W	319.7	31.7	-20.5	-20.5	0.1	114.1	11.3	5.1	5.1	0.2	3.3	7.7	Good	151021A
KN188	FN	Goat	Humerus	W	420.0	41.6	-19.6	-19.6	0.1	149.9	14.8	5.3	5.3	0.2	3.3	1.8	Good	151021A
KN189	FN	Goat	Humerus	W	434.4	42.6	-20.4	-20.4	0.1	156.6	15.3	4.1	4.2	0.2	3.2	8.3	Good	151021A
KN190	FN	Goat	Humerus	W	322.2	28.5	-20.9	-20.9	0.1	113.3	10.0	5.3	5.3	0.2	3.3	5.5	Good	151021A
KN191	FN	Goat	Humerus	W	428.3	38.9	-18.1	-18.2	0.1	152.6	13.9	5.7	5.6	0.2	3.3	2.3	Good	151021B
KN192	FN	Goat	Humerus	W	421.0	40.9	-20.2	-20.2	0.1	149.6	14.5	5.4	5.4	0.2	3.3	2.0	Good	151021A
KN193	FN	Goat	Humerus	W	449.1	40.8	-19.8	-19.8	0.1	162.9	14.8	6.6	6.7	0.4	3.2	5.3	Good	151019B
KN194	FN	Goat	Humerus	W	297.9	26.1	-16.8	-16.8	0.1	106.0	9.3	6.7	6.8	0.4	3.3	4.0	Good	151019B
KN195	FN	Goat	Humerus	W	345.0	34.5	-19.7	-19.7	0.1	120.7	12.1	7.4	7.5	0.4	3.3	4.2	Good	151019B
KN196	FN	Goat	Humerus	W	202.0	18.0	-20.3	-20.3	0.1	70.3	6.3	5.0	5.2	0.4	3.4	2.3	Good	151019B
KN197	FN	Goat	Humerus	W	329.0	29.9	-20.0	-20.0	0.1	117.8	10.7	5.2	5.3	0.4	3.3	6.9	Good	151019B
KN198	FN	Pig	Humerus	W	168.6	16.1	-24.4	-21.6	1.7	22.5	2.1	5.3	7.2	1.1	8.8	3.8	High C:N	150723

KN199	FN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN200	FN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.61	PCP	n/a
KN201	FN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.25	PCP	n/a
KN202	FN	Goat	Humerus	W	189.7	17.4	-20.3	-20.3	0.1	63.9	5.9	5.0	5.1	0.4	3.5	2.0	Good	151019B	
KN203	FN	Goat	Humerus	W	420.1	37.2	-20.4	-20.4	0.1	150.3	13.3	5.2	5.3	0.4	3.3	7.7	Good	151019B	
KN204	FN	Goat	Humerus	W	118.4	11.2	-20.2	-18.5	1.1	40.6	3.8	4.3	6.3	1.2	3.4	2.3	Low N and/or C µg	150723	
KN205	FN	Goat	Humerus	W	354.0	31.0	-19.8	-19.7	0.1	126.8	11.1	5.3	5.4	0.4	3.3	8.6	Good	151019B	
KN206	FN	Goat	Humerus	W	365.4	34.8	-19.9	-19.9	0.1	131.1	12.5	5.1	5.2	0.4	3.3	10.0	Good	151019B	
KN207	FN	Goat	Humerus	W	48.0	4.8	-20.4	-18.7	1.1	14.7	1.5	7.0	8.6	1.0	3.8	3.3	High C:N	150723	
KN208	FN	Goat	Humerus	W	317.3	30.5	-19.0	-18.9	0.1	112.2	10.8	6.0	6.1	0.4	3.3	4.3	Good	151019B	
KN209	FN	Goat	Humerus	W	166.5	16.5	-20.0	-20.0	0.1	57.9	5.7	5.3	5.4	0.4	3.4	3.2	Good	151019B	
KN210	FN	Goat	Humerus	W	190.5	19.0	-19.9	-19.9	0.1	66.1	6.6	5.0	5.1	0.4	3.4	3.4	Good	151019B	
KN211	FN	Goat	Humerus	W	109.9	10.3	-20.0	-18.4	1.1	37.0	3.5	4.1	6.1	1.2	3.5	2.5	Low N and/or C µg	150723	
KN212	FN	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.30	PCP	n/a	
KN213	FN	Goat	Humerus	W	408.6	37.8	-20.1	-20.1	0.1	142.2	13.2	6.0	6.1	0.4	3.4	1.2	Good	151019B	
KN214	FN	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.56	PCP	n/a	
KN215	FN	Goat	Humerus	W	436.7	39.3	-19.9	-19.9	0.1	151.6	13.7	5.4	5.5	0.4	3.4	2.3	Good	151019B	
KN216	FN	Goat	Humerus	W	38.8	3.6	-19.2	-17.8	1.0	12.8	1.2	6.9	8.5	1.0	3.5	1.2	Low N and/or C µg	150723	
KN217	FN	Goat	Humerus	W	32.6	3.3	-21.1	-19.2	1.2	10.1	1.0	3.7	5.7	1.2	3.8	2.7	High C:N	150723	
KN218	FN	Goat	Humerus	W	29.0	2.6	-20.6	-18.8	1.2	8.2	0.7	6.8	8.4	1.0	4.1	1.0	Low N and/or C µg	150723	
KN219	FN	Goat	Humerus	(U)	228.2	19.8	-20.6	-20.6	0.1	78.8	6.8	5.4	5.5	0.4	3.4	1.0	Good	151019B	
KN220	FN	Goat	Humerus	W	196.4	17.5	-19.8	-19.8	0.1	68.5	6.1	4.9	5.1	0.4	3.3	2.8	Good	151019B	
KN221	FN	Goat	Humerus	W	299.1	27.4	-20.4	-20.4	0.1	105.5	9.7	5.3	5.4	0.4	3.3	4.6	Good	151019B	
KN222	FN	Goat	Humerus	W	760.0	67.3	-23.7	-23.8	0.1	289.9	25.7	1.4	1.6	0.4	3.1	7.7	BAE	151019B	
KN223	FN	Goat	Humerus	W	337.0	33.4	-20.3	-20.3	0.1	119.3	11.8	5.2	5.3	0.4	3.3	3.0	Good	151019B	
KN224	FN	Goat	Humerus	W	260.6	25.5	-20.2	-20.2	0.1	90.5	8.9	6.2	6.2	0.2	3.4	2.5	Good	151016	
KN225	FN	Pig	Humerus	W	76.6	6.6	-20.4	-20.4	0.1	26.1	2.2	8.9	8.9	0.2	3.4	3.7	Low N and/or C µg	151016	
KN226	FN	Pig	Humerus	W	177.3	17.6	-20.7	-20.7	0.1	61.1	6.0	4.3	4.3	0.2	3.4	5.6	Good	151016	
KN227	FN	Pig	Humerus	(U)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.06	PCP	n/a	
KN228	FN	Sheep	Humerus	W	451.9	40.7	-20.4	-20.4	0.1	162.1	14.6	4.9	5.0	0.2	3.3	6.9	Good	151016	
KN229	FN	Sheep	Humerus	W	343.9	31.8	-20.6	-20.6	0.1	122.8	11.4	5.2	5.3	0.2	3.3	4.7	Good	151016	
KN230	FN	Sheep	Humerus	W	366.6	33.9	-21.0	-21.0	0.1	130.7	12.1	5.8	5.8	0.2	3.3	8.8	Good	151016	
KN231	FN	Sheep	Humerus	W	347.1	32.1	-21.1	-21.1	0.1	123.7	11.5	7.0	7.1	0.2	3.3	6.5	Good	151016	
KN232	FN	Sheep	Humerus	W	242.9	22.9	-21.3	-21.3	0.1	84.6	8.0	5.0	5.0	0.2	3.3	2.2	Good	151016	
KN233	FN	Sheep	Humerus	W	459.7	38.3	-20.7	-20.7	0.1	158.9	13.2	5.6	5.7	0.2	3.4	0.3	Good	151016	
KN234	FN	Sheep	Humerus	(U)	26.1	2.3	-23.3	-23.3	0.1	6.4	0.6	5.5	5.5	0.2	4.7	2.7	High C:N	151016	
KN235	FN	Sheep	Humerus	W	351.0	33.1	-21.1	-21.1	0.1	124.8	11.8	5.4	5.4	0.2	3.3	5.6	Good	151016	
KN236	FN	Sheep	Humerus	W	82.4	7.9	-21.5	-21.5	0.1	27.1	2.6	4.2	4.2	0.2	3.5	3.0	Low N and/or C µg	151016	
KN237	FN	Sheep	Humerus	W	297.3	26.1	-20.9	-20.9	0.1	105.8	9.3	5.8	5.8	0.2	3.3	7.1	Good	151016	
KN238	FN	Sheep	Humerus	W	184.5	17.4	-20.7	-20.7	0.1	63.4	6.0	6.0	6.0	0.2	3.4	5.1	Good	151016	

KN239	FN	Sheep	Humerus	W	199.6	19.4	-20.8	-20.8	0.1	69.1	6.7	5.5	5.6	0.2	3.4	5.9	Good	151016
KN240	FN	Sheep	Humerus	W	336.9	30.3	-19.9	-19.9	0.1	120.3	10.8	6.5	6.6	0.2	3.3	9.6	Good	151016
KN241	FN	Sheep	Humerus	W	221.3	21.9	-20.9	-20.9	0.1	77.5	7.7	5.3	5.4	0.2	3.3	4.3	Good	151016
KN242	FN	Sheep	Humerus	W	155.9	15.0	-20.9	-20.9	0.1	53.3	5.1	5.0	5.0	0.2	3.4	4.3	Good	151016
KN243	FN	Sheep	Humerus	W	31.4	3.0	-23.0	-23.0	0.1	8.3	0.8	5.0	5.1	0.2	4.4	3.1	High C:N	151016
KN244	FN	Sheep	Humerus	W	288.8	26.0	-20.3	-20.2	0.1	102.0	9.2	5.4	5.5	0.2	3.3	6.8	Good	151016
KN245	FN	Sheep	Humerus	W	122.6	12.3	-21.8	-21.8	0.1	41.5	4.1	5.5	5.6	0.2	3.4	2.3	Low N and/or C µg	151016
KN246	FN	Sheep	Humerus	W	76.4	7.4	-22.1	-22.1	0.1	24.8	2.4	5.6	5.6	0.2	3.6	3.7	Low N and/or C µg	151016
KN247	FN	Sheep	Humerus	W	138.8	13.2	-20.8	-20.8	0.1	47.4	4.5	5.6	5.6	0.2	3.4	4.8	Low N and/or C µg	151016
KN248	FN	Sheep	Humerus	W	45.1	4.4	-21.9	-22.0	0.1	13.5	1.3	6.1	6.2	0.2	3.9	3.4	High C:N	151016
KN249	FN	Sheep	Humerus	W	43.4	3.9	-22.0	-22.0	0.1	12.7	1.2	5.1	5.1	0.2	4.0	3.3	High C:N	151016
KN250	FN	Sheep	Humerus	W	29.7	2.9	-22.3	-22.3	0.1	8.2	0.8	5.7	5.8	0.2	4.3	3.4	High C:N	151016
KN251	FN	Sheep	Humerus	W	15.4	1.5	-26.2	-26.2	0.1	1.5	0.1	3.0	3.1	0.2	11.9	2.4	High C:N	151016
KN252	FN	Sheep	Humerus	(U)	14.3	1.3	-24.9	-24.9	0.1	1.9	0.2	7.8	7.8	0.2	8.7	3.5	High C:N	151016
KN253	FN	Sheep	Humerus	W	28.7	2.6	-21.9	-21.9	0.1	8.3	0.8	6.5	6.5	0.2	4.0	2.3	High C:N	151016
KN254	FN	Sheep	Humerus	W	25.4	2.5	-22.3	-22.3	0.1	6.9	0.7	5.9	5.9	0.2	4.3	2.5	High C:N	151016
KN255	FN	Goat	Humerus	W	351.9	31.1	-20.3	-20.3	0.1	125.3	11.1	6.5	6.5	0.2	3.3	8.6	Good	151016
KN256	FN	Goat	Humerus	W	110.0	9.7	-21.4	-21.4	0.1	34.4	3.0	4.6	4.7	0.2	3.7	1.7	High C:N	151016
KN257	FN	Goat	Humerus	W	207.2	20.5	-19.9	-19.8	0.1	72.4	7.2	5.3	5.3	0.2	3.3	4.8	Good	151016
KN258	FN	Goat	Humerus	W	614.0	58.5	-24.7	-24.7	0.1	234.0	22.3	0.3	0.4	0.3	3.1	4.6	BAE	151016
KN259	FN	Sheep	Humerus	W	250.3	25.0	-20.7	-20.7	0.1	87.7	8.8	4.2	4.3	0.2	3.3	4.7	Good	151019
KN260	FN	Sheep	Humerus	W	32.7	3.2	-22.6	-22.6	0.1	8.8	0.9	5.3	5.4	0.2	4.3	3.9	High C:N	151019
KN261	FN	Sheep	Humerus	W	11.1	1.0	-25.7	-25.7	0.1	1.5	0.1	5.9	6.0	0.2	8.4	2.2	High C:N	151019
KN262	FN	Sheep	Humerus	W	256.9	24.0	-20.8	-20.8	0.1	90.1	8.4	5.0	5.1	0.2	3.3	6.4	Good	151019
KN263	FN	Sheep	Humerus	W	236.9	21.9	-21.1	-21.1	0.1	82.6	7.6	6.5	6.6	0.2	3.3	4.7	Good	151019
KN264	FN	Sheep	Humerus	W	72.1	6.4	-21.3	-21.3	0.1	23.3	2.1	5.1	5.2	0.2	3.6	3.7	High C:N	151019
KN265	FN	Sheep	Humerus	W	50.5	4.4	-22.1	-22.1	0.1	15.3	1.3	5.2	5.3	0.2	3.9	0.7	High C:N	151019
KN266	FN	Sheep	Humerus	W	376.4	37.3	-20.4	-20.4	0.1	132.9	13.2	4.1	4.2	0.2	3.3	4.8	Good	151019
KN267	FN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.09	PCP	n/a
KN268	FN	Sheep	Humerus	(U)	392.3	37.4	-20.6	-20.5	0.1	139.7	13.3	5.6	5.7	0.2	3.3	5.4	Good	151019
KN269	FN	Sheep	Humerus	W	435.0	41.4	-20.6	-20.5	0.1	155.1	14.8	6.9	7.0	0.2	3.3	1.3	Good	151019
KN270	FN	Sheep	Humerus	W	458.4	40.2	-20.8	-20.7	0.1	163.6	14.4	4.7	4.9	0.2	3.3	1.2	Good	151019
KN271	FN	Sheep	Humerus	W	438.5	40.6	-21.0	-20.9	0.1	154.8	14.3	5.8	5.9	0.2	3.3	0.7	Good	151019
KN272	FN	Goat	Humerus	W	395.4	37.0	-20.4	-20.3	0.1	141.2	13.2	5.6	5.7	0.2	3.3	8.7	Good	151019
KN273	FN	Goat	Humerus	W	454.3	40.9	-20.2	-20.2	0.1	163.3	14.7	4.4	4.6	0.2	3.2	4.0	Good	151019
KN274	FN	Sheep	Humerus	W	380.6	35.9	-21.5	-21.5	0.1	135.3	12.8	5.6	5.7	0.2	3.3	5.4	Good	151019
KN275	FN	Sheep	Humerus	W	423.2	37.5	-20.5	-20.5	0.1	151.8	13.4	6.6	6.7	0.2	3.3	6.2	Good	151019
KN276	FN	Sheep	Humerus	W	472.0	41.4	-19.6	-19.5	0.1	167.6	14.7	5.1	5.2	0.2	3.3	3.5	Good	151019
KN277	FN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.06	PCP	n/a
KN278	FN	Sheep	Humerus	W	453.5	39.4	-20.7	-20.7	0.1	156.2	13.6	6.0	6.1	0.2	3.4	1.6	Good	151019

KN279	FN	Sheep	Humerus	W	444.6	40.1	-20.4	-20.3	0.1	157.7	14.2	5.8	5.9	0.2	3.3	1.6	Good	151019
KN280	FN	Sheep	Humerus	W	393.2	38.9	-21.2	-21.2	0.1	138.3	13.7	5.5	5.6	0.2	3.3	1.9	Good	151019
KN281	FN	Sheep	Humerus	W	455.4	42.6	-20.8	-20.7	0.1	163.0	15.2	6.1	6.2	0.2	3.3	2.9	Good	151019
KN282	FN	Sheep	Humerus	W	470.9	41.3	-20.5	-20.4	0.1	168.3	14.8	5.1	5.2	0.2	3.3	3.7	Good	151019
KN283	LN I	Goat	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3.96	PCP	n/a
KN284	MN	Pig	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.52	PCP	n/a
KN285	IN	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.21	PCP	n/a
KN286	FN	Pig	Humerus	(W)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN287	EN	Dog	Pelvis	W	407.4	39.6	-18.9	-18.9	0.1	145.6	14.1	10.2	10.2	0.2	3.3	4.8	Good	151019
KN288	EN	Dog	Mandible	W	413.4	40.5	-19.5	-19.5	0.1	144.4	14.2	7.2	7.3	0.2	3.3	2.5	Good	151019
KN289	MN	Dog	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.12	PCP	n/a
KN290	LN I	Dog	Humerus	W	340.1	34.0	-19.5	-19.4	0.1	121.4	12.1	7.8	7.9	0.2	3.3	9.7	Good	151019
KN291	LN I	Dog	Humerus	W	445.4	41.6	-20.0	-19.9	0.1	159.7	14.9	7.9	8.0	0.2	3.3	4.1	Good	151019
KN292	LN II	Dog	Ulna	W	457.6	40.5	-19.5	-19.4	0.1	164.3	14.5	7.3	7.4	0.2	3.2	4.2	Good	151019
KN293	LN II	Dog	Ulna	(W)	370.9	36.0	-19.7	-19.7	0.1	131.4	12.8	7.0	7.1	0.2	3.3	4.8	Good	151019
KN294	FN	Dog	Ulna	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.50	PCP	n/a
KN295	FN	Dog	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.43	PCP	n/a
KN296	FN	Dog	Ulna	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.96	PCP	n/a
KN297	FN	Dog	Femur	?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.62	PCP	n/a
KN298	LN I	Badger	Ulna	W	459.4	40.3	-19.8	-19.8	0.1	165.9	14.6	5.6	5.7	0.2	3.2	7.7	Good	151019
KN299	FN	Badger	Femur	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.09	PCP	n/a
KN300	FN	Badger	Ulna	(W)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.66	PCP	n/a
KN301	MN	Cattle	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN302	MN	Cattle	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN303	MN	Cattle	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN304	MN	Cattle	Humerus	W	161.3	15.1	-21.2	-21.1	0.1	54.8	5.1	4.6	4.7	0.2	3.4	2.6	Good	151019
KN305	MN	Cattle	Radius	W	74.1	6.8	-20.7	-20.6	0.1	24.8	2.3	4.5	4.7	0.2	3.5	4.2	Low N and/or C µg	151019
KN306	FN	Cattle	Humerus	W	488.5	42.5	-20.1	-20.0	0.1	175.6	15.3	6.1	6.2	0.2	3.2	4.0	Good	151019
KN307	FN	Cattle	Humerus	W	264.5	25.2	-20.7	-20.6	0.1	93.7	8.9	4.8	4.9	0.2	3.3	7.2	Good	151019
KN308	FN	Cattle	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
KN309	FN	Cattle	Humerus	W	96.2	8.4	-21.0	-20.9	0.1	32.9	2.9	4.9	5.0	0.2	3.4	3.0	Low N and/or C µg	151019
KN310	FN	Cattle	Humerus	W	244.5	22.4	-20.7	-20.7	0.1	84.4	7.7	4.4	4.6	0.4	3.4	4.4	Good	151019B
KN311	FN	Cattle	Humerus	W	8.5	0.8	-24.3	-24.4	0.1	1.3	0.1	0.6	0.8	0.4	7.6	2.0	High C:N	151019B
KN312	FN	Cattle	Humerus	W	45.1	4.5	-21.1	-21.1	0.1	15.2	1.5	6.0	6.2	0.4	3.5	3.1	Low N and/or C µg	151019B
KN313	FN	Cattle	Humerus	W	365.3	32.6	-19.4	-19.4	0.1	131.5	11.7	5.0	5.1	0.4	3.2	12.3	Good	151019B
KN314	FN	Cattle	Humerus	W	268.2	25.1	-20.8	-20.8	0.1	95.2	8.9	4.9	5.0	0.4	3.3	5.8	Good	151019B
KN315	FN	Cattle	Humerus	W	145.5	13.2	-20.7	-20.7	0.1	50.7	4.6	5.6	5.7	0.4	3.3	4.1	Low N and/or C µg	151019B
KN316	FN	Cattle	Humerus	W	308.3	27.3	-19.9	-19.9	0.1	85.4	7.6	6.8	6.9	0.4	4.2	4.8	High C:N	151019B
KN317	FN	Cattle	Humerus	W	335.6	32.9	-20.7	-20.7	0.1	119.9	11.8	4.7	4.8	0.4	3.3	8.0	Good	151019B
KN318	FN	Cattle	Humerus	W	32.6	3.2	-19.0	-19.0	0.1	10.2	1.0	5.4	5.5	0.4	3.7	1.9	High C:N	151019B



Table S2b.  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of animal bone collagen from Bronze Age Knossos

Sample No	Excavation	Phase	Species	Element	Weaning Status	C $\mu\text{g}$	%C	$\delta^{13}\text{C}_{(\text{raw})}$	$\delta^{13}\text{C}_{(\text{VPDB})}$	$\delta^{13}\text{C}$ sd	N $\mu\text{g}$	%N	$\delta^{15}\text{N}_{(\text{raw})}$	$\delta^{15}\text{N}_{(\text{AIR})}$	$\delta^{15}\text{N}$ sd	C:N	% Collagen Yield	Sample quality	Runfile
MUM01	MUM	NP	Cattle	Metacarpal	W	459.1	43.3	-20.8	-20.7	0.06	165.3	15.6	5.2	5.4	0.17	3.2	6.3	Good	151207B
MUM02	MUM	NP	Cattle	Metacarpal	W	412.3	37.8	-20.7	-20.5	0.06	147.2	13.5	5.1	5.2	0.17	3.3	10.1	Good	151207B
MUM03	MUM	FP	Goat	Humerus	W	345.0	31.7	-19.4	-19.2	0.07	121.1	11.1	3.4	3.5	0.19	3.3	13.1	Good	151207B
MUM04	MUM	FP	Goat	Humerus	W	454.4	40.6	-19.5	-19.3	0.07	163.9	14.6	3.6	3.7	0.18	3.2	12.0	Good	151207B
MUM05	MUM	FP	Goat	Humerus	W	428.5	39.0	-19.6	-19.4	0.07	152.9	13.9	4.0	4.1	0.18	3.3	10.9	Good	151207B
MUM06	MUM	FP	Goat	Humerus	W	317.2	29.6	-19.4	-19.2	0.07	110.2	10.3	3.9	4.1	0.18	3.4	7.9	Good	151207B
MUM07	MUM	FP	Pig	Humerus	W	403.5	36.0	-19.5	-19.4	0.07	143.4	12.8	6.8	7.0	0.15	3.3	9.9	Good	151207B
MUM08	MUM	FP	Pig	Humerus	W	455.0	41.4	-19.7	-19.6	0.07	165.3	15.0	6.9	7.2	0.15	3.2	9.2	Good	151207B
MUM09	MUM	FP	Sheep	Humerus	(U)	439.7	40.7	-20.5	-20.4	0.06	158.0	14.6	5.6	5.8	0.16	3.2	13.8	Good	151207B
MUM10	MUM	FP	Sheep	Humerus	W	415.6	35.8	-20.3	-20.1	0.07	149.4	12.9	4.9	5.1	0.17	3.2	9.9	Good	151207B
MUM11	MUM	FP	Sheep	Humerus	W	416.2	41.6	-20.8	-20.7	0.06	147.5	14.7	5.0	5.1	0.17	3.3	11.7	Good	151207B
MUM12	MUM	PostP	Horse	Metatarsal	(W)	445.8	39.5	-21.0	-20.9	0.06	161.2	14.3	2.6	2.7	0.20	3.2	10.8	Good	151207B
MUM13	MUM	PostP	Sheep	Humerus	W	439.1	39.6	-20.5	-20.4	0.06	158.8	14.3	4.4	4.6	0.17	3.2	14.6	Good	151207B
MUM14	MUM	PostP	Sheep	Humerus	W	365.6	32.9	-21.1	-21.0	0.06	129.4	11.7	4.6	4.8	0.17	3.3	8.7	Good	151207B
MUM15	MUM	PostP	Goat	Radius	W	392.4	35.4	-19.7	-19.5	0.07	140.1	12.6	6.6	6.8	0.15	3.3	16.0	Good	151207B
MUM16	MUM	PostP	Badger	Femur	W	442.2	42.1	-18.7	-18.5	0.07	157.6	15.0	8.6	8.8	0.14	3.3	15.1	Good	151207B
MUM17	MUM	PostP	Fallow deer	Humerus	W	379.9	36.2	-21.6	-21.4	0.06	133.8	12.7	4.9	5.0	0.17	3.3	12.9	Good	151207B
MUM18	MUM	FP	Fallow deer	Metacarpal	(W)	403.1	39.9	-20.8	-20.7	0.06	144.2	14.3	6.1	6.3	0.16	3.3	15.4	Good	151207B
MUM19	MUM	FP	Dog	Humerus	W	438.6	38.8	-19.0	-18.8	0.07	156.1	13.8	8.0	8.2	0.14	3.3	4.3	Good	151207B
MUM20	MUM	FP	Fallow deer	Calcaneum	(W)	397.2	37.1	-19.5	-19.3	0.07	139.9	13.1	3.6	3.7	0.18	3.3	8.2	Good	151207B
MUM22	MUM	FP	Pig	Humerus	W	248.3	23.4	-21.3	-21.2	0.06	84.3	8.0	2.8	2.9	0.19	3.4	6.2	Good	151207B
MUM23	MUM	FP	Badger	Radius	W	496.5	44.7	-20.9	-20.8	0.07	179.1	16.1	4.7	4.8	0.18	3.2	7.7	Good	160212B
MUM24	MUM	FP	Goat	Metacarpal	W	390.1	37.9	-16.5	-16.2	0.10	140.2	13.6	6.0	6.1	0.18	3.2	11.6	Good	160212B
MUM25	MUM	FP	Goat	Metacarpal	(W)	412.1	39.2	-20.3	-20.2	0.07	145.9	13.9	4.3	4.4	0.18	3.3	6.9	Good	151207B
MUM26	MUM	FP	Goat	Metacarpal	W	434.4	41.0	-19.6	-19.4	0.07	156.3	14.7	4.7	4.8	0.17	3.2	12.7	Good	151207B
MUM27	MUM	FP	Sheep	Metatarsal	W	317.3	28.3	-22.0	-21.9	0.06	109.4	9.8	3.5	3.6	0.18	3.4	5.9	Good	151207B
MUM28	MUM	FP	Goat	Humerus	W	362.4	35.2	-21.3	-21.2	0.06	127.9	12.4	6.1	6.3	0.16	3.3	14.1	Good	151207B
MUM29	MUM	FP	Sheep	Humerus	W	333.6	31.2	-20.7	-20.5	0.06	116.9	10.9	3.9	4.0	0.18	3.3	8.4	Good	151207B
MUM30	MUM	FP	Pig	Scapula	W	421.7	39.8	-20.4	-20.3	0.06	148.8	14.0	6.3	6.5	0.16	3.3	4.4	Good	151207B
MUM31	MUM	FP	Sheep	Humerus	W	436.6	39.7	-20.0	-19.8	0.07	158.1	14.4	4.3	4.4	0.18	3.2	14.4	Good	151207B
MUM32	MUM	FP	Cattle	Humerus	(U)	434.9	39.2	-20.6	-20.5	0.06	155.8	14.0	4.5	4.7	0.17	3.3	8.4	Good	151207B
MUM33	MUM	FP	Cattle	Humerus	W	424.9	38.3	-21.3	-21.2	0.06	154.2	13.9	3.9	4.0	0.18	3.2	9.6	Good	151207B
MUM34	MUM	FP	Cattle	Metatarsal	(W)	221.4	21.5	-19.2	-19.0	0.07	73.7	7.2	6.4	6.7	0.15	3.5	4.4	Good	151207B
MUM35	MUM	FP	Sheep	Humerus	W	434.1	40.9	-20.9	-20.8	0.06	153.8	14.5	4.9	5.0	0.17	3.3	4.5	Good	151207B
MUM36	MUM	FP	Sheep	Humerus	(U)	421.3	39.4	-21.1	-21.0	0.06	149.2	13.9	5.4	5.6	0.16	3.3	3.7	Good	151207B
MUM37	MUM	FP	Sheep	Humerus	W	373.8	37.0	-21.0	-20.9	0.06	133.0	13.2	4.0	4.1	0.18	3.3	7.8	Good	151207B
MUM38	MUM	FP	Sheep	Humerus	W	386.5	34.8	-18.8	-18.6	0.07	137.8	12.4	5.1	5.3	0.17	3.3	11.8	Good	151207B
MUM39	MUM	FP	Sheep	Humerus	W	385.0	37.7	-20.9	-20.8	0.06	136.9	13.4	3.8	3.9	0.18	3.3	9.7	Good	151207B

MUM40	MUM	FP	Sheep	Humerus	W	465.2	43.1	-20.6	-20.5	0.06	168.3	15.6	5.3	5.5	0.17	3.2	14.2	Good	151207B
MUM41	MUM	FP	Goat	Humerus	(U)	454.0	39.5	-20.3	-20.1	0.08	162.0	14.1	5.8	5.9	0.18	3.3	3.7	Good	160212B
MUM42	MUM	FP	Fallow deer	Radius	(W)	441.9	40.9	-20.8	-20.7	0.07	159.7	14.8	4.5	4.6	0.18	3.2	10.8	Good	160212B
MUM43	MUM	FP	Goat	Humerus	W	450.1	42.9	-20.0	-19.8	0.08	163.3	15.5	4.0	4.1	0.19	3.2	12.7	Good	160212B
MUM44	MUM	FP	Sheep	Humerus	W	527.4	46.3	-19.8	-19.6	0.08	193.0	16.9	5.5	5.6	0.18	3.2	10.2	Good	160212B
MUM45	MUM	FP	Sheep	Humerus	W	341.0	29.7	-20.7	-20.5	0.07	121.6	10.6	5.0	5.1	0.18	3.3	7.9	Good	160212B
MUM46	MUM	FP	Goat	Humerus	W	360.5	32.5	-19.6	-19.4	0.08	128.3	11.6	4.2	4.3	0.19	3.3	4.5	Good	160212B
MUM47	MUM	FP	Goat	Humerus	W	455.2	42.1	-19.6	-19.4	0.08	164.8	15.3	4.0	4.1	0.19	3.2	6.6	Good	160212B
MUM48	MUM	FP	Goat	Humerus	W	451.6	41.4	-19.9	-19.8	0.08	161.4	14.8	4.1	4.2	0.19	3.3	5.5	Good	160212B
MUM49	MUM	FP	Goat	Humerus	W	419.1	41.1	-20.0	-19.8	0.08	150.6	14.8	3.4	3.4	0.19	3.2	5.6	Good	160212B
MUM50	MUM	FP	Goat	Humerus	W	345.3	32.6	-19.0	-18.8	0.08	123.1	11.6	4.0	4.0	0.19	3.3	10.5	Good	160212B
MUM51	MUM	FP	Goat	Humerus	W	368.3	33.2	-19.4	-19.2	0.08	131.5	11.8	4.7	4.8	0.18	3.3	7.4	Good	160212B
MUM52	MUM	FP	Pig	Humerus	W	430.3	41.4	-21.1	-21.0	0.07	155.1	14.9	4.7	4.8	0.18	3.2	10.2	Good	160212B
MUM53	MUM	FP	Pig	Humerus	W	418.4	38.7	-20.1	-19.9	0.08	151.0	14.0	8.1	8.3	0.19	3.2	6.4	Good	160212B
MUM54	MUM	FP	Pig	Humerus	W	452.9	41.5	-20.1	-19.9	0.08	161.9	14.9	6.4	6.5	0.18	3.3	8.5	Good	160212B
MUM55	MUM	FP	Pig	Humerus	(U)	285.2	25.9	-19.4	-19.2	0.08	98.4	8.9	7.2	7.3	0.18	3.4	4.4	Good	160212B
MUM56	MUM	FP	Pig	Humerus	(U)	456.4	39.7	-20.3	-20.1	0.08	165.3	14.4	7.3	7.4	0.18	3.2	5.9	Good	160212B
MUM57	MUM	FP	Pig	Humerus	U	494.5	45.4	-20.9	-20.7	0.07	179.1	16.4	5.8	5.9	0.18	3.2	15.3	Good	160212B
MUM58	MUM	FP	Pig	Humerus	W	371.9	32.6	-20.8	-20.7	0.07	131.5	11.5	4.6	4.6	0.18	3.3	1.6	Good	160212B
MUM59	MUM	FP	Fallow deer	Tibia	W	471.5	42.5	-19.5	-19.3	0.08	168.9	15.2	4.1	4.1	0.19	3.3	8.8	Good	160212B
MUM60	MUM	FP	Fallow deer	Femur	W	474.7	44.4	-20.1	-19.9	0.08	171.0	16.0	4.2	4.2	0.19	3.2	8.9	Good	160212B
MUM61	MUM	FP	Fallow deer	Tibia	(W)	445.0	44.9	-20.2	-20.1	0.08	162.0	16.4	3.6	3.6	0.19	3.2	13.8	Good	160212B
MUM62	MUM	NP	Sheep	Humerus	W	466.3	45.3	-21.0	-20.8	0.07	166.2	16.1	4.2	4.2	0.19	3.3	5.2	Good	160212B
MUM63	MUM	NP	Sheep	Humerus	W	505.9	44.0	-21.2	-21.0	0.07	183.7	16.0	5.3	5.4	0.18	3.2	6.1	Good	160212B
MUM64	MUM	NP	Goat	Radius	(W)	499.0	45.0	-19.8	-19.6	0.08	181.7	16.4	3.2	3.2	0.19	3.2	8.9	Good	160212B
MUM65	MUM	NP	Goat	Humerus	W	473.6	42.7	-20.2	-20.0	0.08	170.1	15.3	3.7	3.7	0.19	3.2	5.4	Good	160212B
MUM66	MUM	FP	Pig	Humerus	W	486.1	46.7	-20.5	-20.3	0.07	174.7	16.8	4.9	5.0	0.18	3.2	4.9	Good	160212B
MUM68	MUM	NP	Sheep	Mandible	(U)	460.7	41.9	-19.7	-19.6	0.08	165.6	15.1	6.3	6.4	0.18	3.2	5.3	Good	160212B
MUM70	MUM	NP	Goat	Mandible	W	496.8	44.0	-19.5	-19.3	0.08	179.7	15.9	2.9	2.9	0.20	3.2	6.0	Good	160212B
MUM71	MUM	NP	Goat	Mandible	W	413.2	37.6	-20.0	-19.8	0.08	148.7	13.5	3.8	3.9	0.19	3.2	5.3	Good	160212B
MUM72	MUM	FP	Sheep	Mandible	W	427.9	42.0	-20.8	-20.7	0.07	147.8	14.5	4.3	4.4	0.19	3.4	2.0	Good	160212B
MUM73	MUM	FP	Goat	Mandible	W	475.1	43.6	-20.5	-20.4	0.07	162.3	14.9	3.9	3.9	0.19	3.4	1.3	Good	160212B
MUM74	MUM	FP	Goat	Mandible	W	484.5	44.9	-20.2	-20.0	0.08	175.2	16.2	3.4	3.5	0.19	3.2	12.2	Good	160212B
MUM75	MUM	FP	Sheep	Mandible	W	420.9	42.1	-20.2	-20.0	0.08	144.4	14.4	7.6	7.7	0.18	3.4	2.7	Good	160212B
MUM76	MUM	FP	Sheep	Mandible	(U)	448.4	42.3	-21.4	-21.3	0.07	153.5	14.5	6.0	6.1	0.18	3.4	n/a	Good	160212B
MUM77	MUM	FP	Sheep	Mandible	W	480.4	42.5	-17.6	-17.4	0.09	170.4	15.1	6.4	6.5	0.18	3.3	3.7	Good	160212B
MUM78	MUM	FP	Goat	Mandible	W	494.0	44.5	-20.1	-20.0	0.08	178.6	16.1	3.3	3.4	0.19	3.2	11.8	Good	160212B
RR001	RRN	PreP	Pig	Humerus	U	127.9	12.7	-20.4	-20.3	0.06	37.2	3.7	4.5	4.7	0.17	4.0	2.0	High C:N	151207B
RR002	RRN	PreP	Pig	Humerus	W	170.4	15.5	-20.3	-20.2	0.07	53.1	4.8	3.3	3.5	0.19	3.7	4.2	High C:N	151207B
RR003	RRN	PreP	Pig	Humerus	W	180.5	15.8	-20.6	-20.5	0.06	57.2	5.0	4.7	4.9	0.17	3.7	5.0	High C:N	151207B

RR004	RRN	PreP	Pig	Humerus	(W)	139.6	12.5	-20.6	-20.4	0.06	42.3	3.8	4.0	4.1	0.18	3.8	4.6	High C:N	151207B
RR005	RRN	PreP	Sheep	Humerus	W	154.6	14.9	-20.7	-20.6	0.06	46.1	4.4	3.7	3.8	0.18	3.9	2.6	High C:N	151207B
RR006	RRN	PreP	Sheep	Humerus	W	425.2	40.1	-21.5	-21.3	0.06	148.9	14.0	5.0	5.1	0.17	3.3	32.4	Good	151207B
RR007	RRN	PreP	Sheep	Humerus	W	180.2	16.4	-20.4	-20.2	0.06	56.9	5.2	4.6	4.7	0.17	3.7	4.2	High C:N	151207B
RR008	RRN	PreP	Sheep	Humerus	W	392.8	35.4	-20.8	-20.7	0.06	138.4	12.5	4.9	5.1	0.17	3.3	11.8	Good	151207B
RR009	RRN	PreP	Sheep	Humerus	W	344.1	32.8	-20.5	-20.3	0.08	121.7	11.6	3.8	3.9	0.21	3.3	6.1	Good	151207
RR010	RRN	PreP	Sheep	Humerus	W	101.6	9.4	-20.8	-20.7	0.08	30.8	2.8	4.2	4.4	0.20	3.9	3.7	High C:N	151207
RR011	RRN	PreP	Sheep	Humerus	W	213.0	20.9	-19.9	-19.8	0.08	70.7	6.9	3.7	3.8	0.21	3.5	3.4	Good	151207
RR012	RRN	PreP	Sheep	Humerus	W	194.5	17.1	-20.9	-20.8	0.08	63.9	5.6	2.7	2.8	0.22	3.6	4.5	Low N and/or C µg	151207
RR013	RRN	PreP	Goat	Humerus	W	436.6	38.0	-20.8	-20.7	0.08	156.6	13.6	5.7	5.9	0.18	3.3	12.3	Good	151207
RR014	RRN	PreP	Goat	Humerus	W	138.8	12.7	-21.3	-21.2	0.08	43.5	4.0	3.7	3.8	0.21	3.7	6.1	High C:N	151207
RR015	RRN	PreP	Goat	Humerus	W	6.6	0.6	-25.9	-25.9	0.08	1.1	0.1	-3.5	-3.5	0.31	7.3	2.3	High C:N	151207
RR016	RRN	PreP	Goat	Humerus	W	366.3	33.0	-20.2	-20.1	0.08	129.8	11.7	3.8	3.9	0.21	3.3	8.9	Good	151207
RR017	RRN	NP	Goat	Humerus	W	383.9	36.6	-20.4	-20.3	0.08	134.7	12.8	3.9	4.1	0.20	3.3	11.1	Good	151207
RR018	RRN	NP	Goat	Humerus	W	384.1	36.2	-21.3	-21.2	0.08	135.7	12.8	4.5	4.6	0.20	3.3	12.6	Good	151207
RR019	RRN	NP	Goat	Humerus	(U)	421.0	39.0	-19.9	-19.8	0.08	150.8	14.0	5.2	5.4	0.19	3.3	12.9	Good	151207
RR020	RRN	NP	Goat	Humerus	W	272.0	26.9	-19.6	-19.4	0.08	94.3	9.3	3.9	4.1	0.20	3.4	6.5	Good	151207
RR021	RRN	NP	Goat	Humerus	W	288.5	28.6	-19.6	-19.4	0.08	102.3	10.1	4.7	4.8	0.18	3.3	7.2	Good	160212
RR022	RRN	NP	Goat	Humerus	W	326.7	30.5	-20.1	-19.9	0.13	113.6	10.6	3.0	2.9	0.20	3.4	3.5	Good	160211
RR023	RRN	NP	Goat	Humerus	W	412.1	38.5	-20.2	-20.0	0.08	146.4	13.7	3.5	3.6	0.21	3.3	13.1	Good	151207
RR024	RRN	NP	Goat	Humerus	W	302.4	27.7	-20.5	-20.3	0.08	104.5	9.6	3.7	3.8	0.21	3.4	9.7	Good	151207
RR025	RRN	NP	Pig	Humerus	(W)	443.8	40.7	-21.3	-21.2	0.08	159.0	14.6	3.8	3.9	0.21	3.3	11.9	Good	151207
RR026	RRN	NP	Pig	Femur	(W)	432.4	42.4	-21.2	-21.1	0.07	152.9	15.0	4.8	4.9	0.18	3.3	2.4	Good	160212
RR027	RRN	NP	Pig	Humerus	W	491.4	44.3	-20.5	-20.3	0.08	171.6	15.5	5.9	6.0	0.18	3.3	1.8	Good	160212
RR028	RRN	NP	Pig	Humerus	(U)	462.2	41.6	-20.8	-20.7	0.13	165.1	14.9	5.4	5.4	0.18	3.3	5.1	Good	160211
RR029	RRN	NP	Pig	Humerus	(U)	458.1	42.0	-20.6	-20.4	0.13	164.6	15.1	5.3	5.3	0.18	3.2	7.6	Good	160211
RR030	RRN	NP	Pig	Humerus	W	470.0	43.1	-19.1	-18.9	0.09	170.5	15.6	7.5	7.7	0.18	3.2	8.9	Good	160212
RR031	RRN	NP	Pig	Humerus	W	471.9	41.4	-20.1	-19.9	0.13	169.6	14.9	5.4	5.4	0.18	3.2	3.4	Good	160211
RR032	RRN	NP	Pig	Humerus	W	438.8	42.6	-20.2	-20.0	0.13	157.1	15.3	7.0	7.0	0.18	3.3	5.6	Good	160211
RR033	RRN	NP	Pig	Humerus	W	193.9	18.0	-21.0	-20.9	0.07	67.7	6.3	4.4	4.5	0.18	3.3	5.1	Low N and/or C µg	160212
RR034	RRN	NP	Pig	Humerus	U	237.7	21.0	-19.9	-19.7	0.13	80.2	7.1	4.9	4.9	0.18	3.5	4.5	Good	160211
RR035	RRN	NP	Pig	Humerus	W	466.6	45.7	-20.9	-20.7	0.08	169.0	16.6	5.0	5.1	0.18	3.2	7.4	Good	160212
RR036	RRN	NP	Pig	Humerus	U	214.0	20.4	-20.4	-20.2	0.08	69.9	6.7	6.5	6.6	0.18	3.6	0.5	Good	160212
RR037	RRN	NP	Pig	Humerus	U	272.1	25.4	-20.3	-20.1	0.08	94.8	8.9	4.4	4.5	0.18	3.3	2.5	Good	160212
RR038	RRN	NP	Pig	Humerus	U	449.7	43.7	-20.0	-19.8	0.08	161.8	15.7	6.9	7.0	0.18	3.2	8.7	Good	160212
RR039	RRN	NP	Goat	Humerus	W	458.3	45.4	-18.7	-18.4	0.09	161.4	16.0	4.2	4.3	0.18	3.3	3.8	Good	160212
RR040	RRN	NP	Goat	Humerus	W	206.5	19.9	-20.2	-20.0	0.08	71.1	6.8	3.5	3.5	0.18	3.4	3.0	Good	160212
RR041	RRN	NP	Goat	Humerus	W	382.1	36.0	-20.3	-20.1	0.08	135.0	12.7	3.2	3.3	0.19	3.3	4.8	Good	160212
RR042	RRN	NP	Goat	Humerus	W	500.7	43.9	-20.1	-20.0	0.13	180.3	15.8	3.6	3.5	0.19	3.2	5.1	Good	160211
RR043	RRN	NP	Goat	Humerus	W	226.5	21.4	-20.4	-20.3	0.13	75.9	7.2	3.7	3.6	0.19	3.5	3.2	Good	160211

RR044	RRN	NP	Goat	Humerus	W	475.0	43.6	-20.1	-19.9	0.13	171.8	15.8	4.4	4.3	0.19	3.2	10.4	Good	160211
RR045	RRN	NP	Goat	Humerus	W	476.8	43.3	-20.0	-19.8	0.08	173.0	15.7	4.4	4.5	0.18	3.2	13.8	Good	160212
RR046	RRN	NP	Goat	Humerus	W	238.2	23.1	-20.3	-20.2	0.13	79.8	7.8	4.2	4.2	0.19	3.5	4.6	Good	160211
RR047	RRN	NP	Goat	Humerus	W	428.2	43.3	-20.5	-20.4	0.08	153.4	15.5	3.9	4.0	0.18	3.3	8.1	Good	160212
RR048	RRN	NP	Sheep	Humerus	W	391.7	36.6	-21.2	-21.0	0.07	138.9	13.0	4.6	4.7	0.18	3.3	2.8	Good	160212
RR049	RRN	NP	Sheep	Humerus	W	501.1	44.0	-20.9	-20.7	0.08	179.0	15.7	4.7	4.8	0.18	3.3	3.9	Good	160212
RR050	RRN	NP	Sheep	Humerus	(U)	336.9	32.4	-20.5	-20.3	0.08	119.5	11.5	5.9	6.1	0.18	3.3	4.3	Good	160212
RR051	RRN	NP	Sheep	Humerus	W	411.7	39.6	-20.3	-20.2	0.13	144.7	13.9	5.5	5.5	0.18	3.3	4.1	Good	160211
RR052	RRN	NP	Sheep	Humerus	W	484.8	44.9	-20.7	-20.6	0.13	177.6	16.4	5.0	4.9	0.18	3.2	13.3	Good	160211
RR053	RRN	NP	Sheep	Humerus	W	515.8	46.1	-20.1	-19.9	0.08	188.9	16.9	3.3	3.4	0.19	3.2	13.9	Good	160212
RR054	RRN	NP	Goat	Humerus	(U)	212.5	20.2	-21.2	-21.1	0.13	71.3	6.8	6.3	6.3	0.18	3.5	4.4	Good	160211
RR055	RRN	NP	Sheep	Humerus	W	267.9	25.3	-20.7	-20.6	0.13	92.0	8.7	3.2	3.1	0.19	3.4	4.3	Good	160211
RR056	RRN	NP	Sheep	Humerus	W	543.7	48.5	-20.9	-20.8	0.07	199.8	17.8	4.9	5.0	0.18	3.2	13.4	Good	160212
RR057	RRN	NP	Sheep	Humerus	W	449.3	40.1	-21.3	-21.1	0.07	159.9	14.3	6.1	6.2	0.18	3.3	1.3	Good	160212
RR058	RRN	NP	Sheep	Humerus	W	481.4	42.6	-20.0	-19.8	0.13	174.9	15.5	4.3	4.2	0.19	3.2	8.3	Good	160211
RR059	RRN	NP	Sheep	Humerus	(U)	493.9	42.2	-19.9	-19.7	0.08	172.6	14.8	5.8	5.9	0.18	3.3	1.5	Good	160212
																		Low N and/or C	
RR060	RRN	NP	Sheep	Humerus	W	195.0	17.7	-20.8	-20.7	0.13	65.2	5.9	4.1	4.0	0.19	3.5	3.6	µg	160211
RR061	RRN	NP	Sheep	Humerus	W	406.8	38.7	-20.5	-20.3	0.08	145.9	13.9	5.6	5.7	0.18	3.3	5.8	Good	160212
RR062	RRN	NP	Sheep	Humerus	(U)	244.0	23.0	-21.7	-21.5	0.07	81.0	7.6	4.7	4.8	0.18	3.5	3.6	Good	160212
RR063	RRN	NP	Sheep	Humerus	W	379.6	35.1	-21.1	-21.0	0.13	134.8	12.5	5.3	5.3	0.18	3.3	6.3	Good	160211
RR064	RRN	NP	Sheep	Humerus	W	441.7	42.5	-20.5	-20.4	0.13	159.7	15.4	4.9	4.8	0.18	3.2	10.1	Good	160211
RR065	RRN	NP	Sheep	Humerus	W	396.4	34.8	-20.3	-20.1	0.13	142.2	12.5	6.1	6.0	0.18	3.3	8.9	Good	160211
RR066	RRN	NP	Sheep	Humerus	W	449.1	41.2	-21.3	-21.1	0.07	162.0	14.9	4.7	4.8	0.18	3.2	5.6	Good	160212
RR067	RRN	NP	Dog	Radius	W	324.5	32.1	-17.6	-17.4	0.10	116.5	11.5	8.9	9.0	0.19	3.2	5.0	Good	160212
RR068	RRN	NP	Sheep	Humerus	W	457.0	43.5	-20.2	-20.0	0.08	165.3	15.7	6.0	6.1	0.18	3.2	6.9	Good	160212
RR069	RRN	NP	Sheep	Humerus	W	439.3	41.1	-20.8	-20.6	0.13	158.6	14.8	4.1	4.0	0.19	3.2	7.2	Good	160211
RR070	RRN	NP	Sheep	Humerus	W	459.5	44.2	-20.9	-20.8	0.13	164.7	15.8	6.0	5.9	0.18	3.3	4.2	Good	160211
RR071	RRN	NP	Sheep	Humerus	W	504.9	45.5	-20.3	-20.2	0.13	185.0	16.7	7.0	7.0	0.18	3.2	11.5	Good	160211
RR072	RRS	FP	Dog	Humerus	W	493.1	44.0	-18.5	-18.3	0.13	176.5	15.8	8.9	8.9	0.19	3.3	3.2	Good	160211
RR073	RRS	LPreP	Sheep	Humerus	W	425.5	39.8	-20.8	-20.6	0.13	151.9	14.2	6.0	6.0	0.18	3.3	4.9	Good	160211
RR074	RRS	LPreP	Sheep	Humerus	W	357.8	35.1	-20.1	-20.0	0.08	125.2	12.3	4.3	4.5	0.20	3.3	7.2	Good	151207
RR075	RRS	LPreP	Sheep	Humerus	W	411.5	38.8	-20.9	-20.8	0.08	146.5	13.8	4.6	4.8	0.19	3.3	5.9	Good	151207
RR076	RRS	LPreP	Sheep	Humerus	W	410.4	38.4	-21.5	-21.4	0.08	146.5	13.7	5.2	5.4	0.19	3.3	8.9	Good	151207
RR077	RRS	LPreP	Sheep	Humerus	W	432.3	38.3	-21.2	-21.1	0.08	151.6	13.4	4.2	4.4	0.20	3.3	0.9	Good	151207
RR078	RRS	LPreP	Sheep	Humerus	W	319.3	29.3	-20.8	-20.7	0.08	110.1	10.1	4.4	4.6	0.20	3.4	4.1	Good	151207
RR079	RRS	LPreP	Sheep	Humerus	W	221.6	20.1	-21.9	-21.8	0.08	72.2	6.6	3.7	3.9	0.21	3.6	1.1	Good	151207
RR080	RRS	LPreP	Sheep	Humerus	W	424.0	37.9	-20.6	-20.5	0.08	151.8	13.6	5.4	5.6	0.19	3.3	11.2	Good	151207
RR081	RRS	LPreP	Sheep	Humerus	W	279.8	28.0	-20.9	-20.7	0.08	98.1	9.8	4.9	5.0	0.18	3.3	3.7	Good	160212
RR082	RRS	LPreP	Sheep	Humerus	W	259.1	25.6	-20.5	-20.3	0.08	91.7	9.1	5.7	5.8	0.18	3.3	3.9	Good	160212
RR083	RRS	LPreP	Goat	Humerus	W	273.1	25.3	-20.3	-20.2	0.13	93.6	8.7	3.4	3.2	0.19	3.4	3.9	Good	160211

RR084	RRS	LPreP	Goat	Humerus	W	323.0	29.6	-20.9	-20.7	0.08	115.0	10.6	4.6	4.7	0.18	3.3	4.6	Good	160212
RR085	RRS	LPreP	Goat	Humerus	W	193.1	18.0	-20.0	-19.9	0.13	64.0	6.0	3.8	3.7	0.19	3.5	3.7	Low N and/or C µg	160211
RR086	RRS	LPreP	Goat	Humerus	W	242.0	22.6	-20.7	-20.5	0.08	84.2	7.9	4.0	4.1	0.18	3.4	3.3	Good	160212
RR087	RRS	LPreP	Goat	Humerus	W	239.8	22.0	-21.6	-21.5	0.13	81.3	7.5	6.0	5.9	0.18	3.4	3.9	Good	160211
RR088	RRS	LPreP	Goat	Humerus	W	312.5	27.7	-20.4	-20.3	0.13	109.1	9.7	3.7	3.6	0.19	3.3	7.3	Good	160211
RR089	RRS	LPreP	Goat	Humerus	W	514.7	45.5	-20.1	-19.9	0.13	187.5	16.6	4.4	4.3	0.19	3.2	10.9	Good	160211
RR090	RRS	LPreP	Goat	Humerus	W	207.9	18.9	-20.2	-20.0	0.13	70.0	6.4	3.6	3.5	0.19	3.5	3.2	Good	160211
RR091	RRS	LPreP	Pig	Humerus	W	55.1	5.0	-22.0	-21.9	0.07	16.8	1.5	3.9	4.0	0.18	3.8	2.2	High C:N	160212
RR092	RRS	LPreP	Pig	Humerus	W	218.1	19.5	-21.5	-21.3	0.07	76.5	6.8	4.2	4.3	0.18	3.3	2.7	Good	160212
RR093	RRS	LPreP	Pig	Humerus	W	326.0	30.8	-20.5	-20.4	0.13	114.5	10.8	4.2	4.2	0.19	3.3	4.7	Good	160211
RR094	RRS	LPreP	Pig	Humerus	W	199.7	19.2	-20.1	-19.9	0.13	67.3	6.5	4.2	4.1	0.19	3.5	2.8	Low N and/or C µg	160211
RR095	RRS	LPreP	Pig	Humerus	W	286.4	24.9	-21.3	-21.2	0.13	98.6	8.6	4.4	4.4	0.19	3.4	4.0	Good	160211
RR096	RRS	LPreP	Pig	Humerus	W	431.6	37.5	-20.6	-20.4	0.13	155.0	13.5	5.2	5.1	0.18	3.2	9.2	Good	160211
RR097	RRS	LPreP	Cattle	Humerus	W	113.7	9.9	-21.3	-21.2	0.13	35.7	3.1	3.4	3.2	0.19	3.7	2.3	High C:N	160211
RR098	RRS	LPreP	Cattle	Humerus	W	353.7	32.4	-21.0	-20.9	0.07	127.3	11.7	5.2	5.3	0.18	3.2	7.1	Good	160212
RR099	RRS	LPreP	Cattle	Humerus	W	291.6	25.6	-21.0	-20.8	0.07	103.3	9.1	5.3	5.4	0.18	3.3	5.9	Good	160212
RR100	RRS	LPreP	Cattle	Humerus	W	212.6	18.6	-20.8	-20.6	0.08	73.9	6.5	5.6	5.7	0.18	3.4	5.7	Good	160212
RR101	RRS	LPreP	Cattle	Humerus	W	418.4	37.0	-21.1	-21.0	0.13	147.9	13.1	6.4	6.4	0.18	3.3	8.1	Good	160211
RR102	RRS	NP	Cattle	Metacarpal	W	54.3	5.3	-22.8	-22.7	0.07	13.6	1.3	1.9	2.0	0.20	4.6	0.5	High C:N	160212
RR103	RRN	NP	Cattle	Metacarpal	W	263.9	25.1	-20.9	-20.8	0.07	93.1	8.9	5.6	5.7	0.18	3.3	4.6	Good	160212
RR104	RRN	NP	Cattle	Metacarpal	W	175.5	16.9	-20.7	-20.5	0.07	59.2	5.7	3.3	3.3	0.19	3.5	2.9	Low N and/or C µg	160212B
RR105	RRN	NP	Cattle	Metacarpal (W)	W	262.2	24.5	-20.5	-20.3	0.08	90.6	8.5	5.8	5.9	0.18	3.4	3.0	Good	160212
RR106	RRS	FP	Cattle	Metacarpal	W	414.9	36.7	-21.0	-20.9	0.07	149.6	13.2	4.7	4.8	0.18	3.2	7.6	Good	160212B
RR107	RRS	FP	Cattle	Metacarpal	W	289.2	27.5	-20.1	-19.9	0.08	102.6	9.8	6.1	6.3	0.18	3.3	6.2	Good	160212
RR108	RRS	FP	Cattle	Metacarpal	W	259.7	24.0	-19.9	-19.7	0.08	91.2	8.4	5.8	5.9	0.18	3.3	5.3	Good	160212
RR109	RRN	NP	Cattle	Metacarpal	W	13.1	1.2	-24.9	-24.9	0.06	2.4	0.2	-3.5	-3.5	0.28	6.3	3.1	High C:N	160212
RR110	RRN	NP	Cattle	Metacarpal (W)	W	386.9	33.4	-21.4	-21.2	0.07	139.6	12.0	5.0	5.1	0.18	3.2	7.9	Good	160212
RR111	RRN	NP	Cattle	Metacarpal	W	228.7	20.2	-21.0	-20.8	0.07	79.5	7.0	4.8	4.9	0.18	3.4	4.7	Good	160212B
RR112	RRN	NP	Cattle	Metacarpal	W	308.2	29.1	-21.0	-20.9	0.07	109.9	10.4	5.2	5.3	0.18	3.3	7.0	Good	160212B
RR113	RRN	NP	Cattle	Metacarpal	W	445.6	40.5	-18.8	-18.6	0.08	161.2	14.7	4.0	4.1	0.19	3.2	8.4	Good	160212B
RR114	RRN	NP	Cattle	Metatarsal	W	187.0	17.6	-20.5	-20.3	0.08	64.8	6.1	6.1	6.2	0.18	3.4	5.2	Low N and/or C µg	160212
RR115	RRN	NP	Cattle	Metatarsal	W	431.3	42.7	-20.4	-20.2	0.08	155.8	15.4	5.6	5.7	0.18	3.2	6.6	Good	160212B
RR116	RRN	NP	Cattle	Metatarsal	W	481.7	45.4	-20.4	-20.3	0.08	174.8	16.5	6.6	6.7	0.18	3.2	9.3	Good	160212
RR117	RRN	NP	Cattle	Metacarpal	W	349.9	31.8	-21.0	-20.9	0.07	125.7	11.4	4.1	4.2	0.19	3.2	9.4	Good	160212B
RR118	RRN	NP	Cattle	Metacarpal	W	302.6	28.0	-20.9	-20.7	0.08	108.0	10.0	5.6	5.7	0.18	3.3	9.0	Good	160212
RR119	RRN	NP	Cattle	Metatarsal	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
RR120	RRN	NP	Cattle	Metatarsal	W	343.7	33.1	-20.3	-20.1	0.08	123.4	11.9	5.0	5.1	0.18	3.2	9.9	Good	n/a
RR121	RRS	NP	Cattle	Metatarsal	W	177.7	16.2	-21.7	-21.6	0.08	58.7	5.3	3.5	3.6	0.21	3.5	4.6	Low N and/or C µg	151207
RR122	RRN	NP	Cattle	Metatarsal	W	370.7	35.6	-21.3	-21.2	0.08	131.3	12.6	4.5	4.6	0.20	3.3	14.2	Good	151207
RR123	RR	NP	Cattle	Metatarsal (W)	W	374.5	36.0	-21.2	-21.1	0.08	133.7	12.9	4.2	4.3	0.20	3.3	10.8	Good	151207

RR124	RR	NP	Cattle	Metatarsal	(W)	361.7	33.5	-20.5	-20.4	0.08	128.3	11.9	6.9	7.1	0.17	3.3	11.4	Good	151207
RR125	RR	FP	Dog	Radius	?	302.5	30.0	-19.6	-19.4	0.08	104.9	10.4	6.6	6.8	0.17	3.4	10.8	Good	151207
RR126	RRS	PostP	Pig	Humerus	W	321.5	30.3	-20.3	-20.2	0.08	112.4	10.6	4.7	4.8	0.19	3.3	5.6	Good	151207
RR127	RRS	OP	Goat	Humerus	W	232.8	21.6	-20.2	-20.1	0.08	78.2	7.2	1.3	1.4	0.24	3.5	4.5	Good	151207
RR128	RRS	OP	Goat	Humerus	W	193.3	17.7	-20.7	-20.6	0.08	63.4	5.8	2.9	3.1	0.22	3.6	4.7	Low N and/or C µg	151207
RR129	RRS	OP	Goat	Humerus	W	414.5	40.2	-19.6	-19.4	0.08	147.5	14.3	4.7	4.8	0.19	3.3	15.5	Good	151207
RR130	EH93	OP	Goat	Humerus	W	343.6	34.0	-20.0	-19.9	0.08	119.8	11.9	3.1	3.2	0.21	3.3	9.2	Good	151207
RR131	RT	OP	Pig	Humerus	W	325.2	31.3	-20.9	-20.7	0.08	113.6	10.9	4.6	4.7	0.20	3.3	9.6	Good	151207
RR132	RT	OP	Pig	Humerus	W	365.9	31.8	-21.1	-20.9	0.08	129.4	11.3	4.2	4.3	0.20	3.3	10.9	Good	151207
RR133	RRS	OP	Pig	Humerus	W	232.4	23.0	-20.5	-20.3	0.08	78.0	7.7	4.1	4.2	0.20	3.5	7.3	Good	151207
RR134	RRS	OP	Pig	Humerus	W	367.7	33.4	-20.6	-20.4	0.08	129.0	11.7	5.5	5.6	0.18	3.3	10.0	Good	151207
RR135	AQ	OP	Pig	Humerus	W	329.2	31.7	-21.2	-21.1	0.08	114.4	11.0	3.8	3.9	0.21	3.4	7.8	Good	151207
RR136	AQ	OP	Pig	Humerus	W	367.6	35.3	-20.0	-19.9	0.08	130.4	12.5	5.5	5.6	0.18	3.3	6.4	Good	151207
RR137	RRS	LPreP	Cattle	Metacarpal	W	197.9	17.5	-20.8	-20.7	0.08	65.5	5.8	2.9	3.0	0.22	3.5	6.4	Low N and/or C µg	151207
RR138	RRS	LPreP	Cattle	Metacarpal	W	266.7	25.2	-21.2	-21.0	0.08	91.0	8.6	4.0	4.2	0.20	3.4	8.1	Good	151207
RR139	RT	OP	Cattle	Humerus	W	379.9	34.5	-21.1	-21.0	0.08	133.6	12.1	3.5	3.6	0.21	3.3	4.0	Good	151207
RR140	AQ	OP	Cattle	Humerus	W	270.8	24.8	-21.4	-21.3	0.08	92.7	8.5	4.2	4.3	0.20	3.4	2.8	Good	151207
RR141	RRS	OP	Sheep	Mandible	W	314.4	30.5	-20.0	-19.9	0.08	109.5	10.6	4.6	4.7	0.20	3.3	13.6	Good	151207
RR142	RRS	OP	Sheep	Mandible	(U)	434.5	40.2	-21.6	-21.4	0.08	155.1	14.4	5.7	5.9	0.18	3.3	13.0	Good	151207
RR144	RRS	OP	Sheep	Humerus	W	360.5	36.0	-20.9	-20.8	0.08	127.6	12.8	3.8	3.9	0.21	3.3	7.7	Good	151207
RR145	EH93	OP	Sheep	Humerus	W	137.3	13.3	-21.2	-21.1	0.08	42.8	4.2	4.6	4.7	0.20	3.7	6.4	High C:N	151207
RR146	RRS	OP	Sheep	Humerus	(U)	405.8	38.3	-20.9	-20.8	0.08	140.6	13.3	3.8	3.9	0.21	3.4	4.1	Good	151207
RR147	RT	OP	Sheep	Humerus	W	85.2	8.0	-20.9	-20.7	0.08	23.4	2.2	2.7	2.8	0.22	4.2	3.5	High C:N	151207
RR148	RRS	OP	Sheep	Humerus	W	422.3	37.4	-21.6	-21.5	0.08	152.0	13.5	4.4	4.6	0.20	3.2	15.4	Good	151207
RR149	RRS	OP	Sheep	Humerus	W	296.7	28.3	-21.2	-21.1	0.08	103.0	9.8	4.4	4.5	0.20	3.4	8.9	Good	151207
RR150	RRS	OP	Sheep	Humerus	W	350.7	31.3	-21.6	-21.4	0.08	122.0	10.9	0.3	0.4	0.25	3.4	5.8	BAE	151207
RR151	RRS	OP	Sheep	Humerus	W	298.9	28.2	-21.3	-21.2	0.08	103.3	9.7	4.5	4.6	0.20	3.4	7.4	Good	151207
RR152	RRS	OP	Sheep	Humerus	W	219.1	20.5	-21.6	-21.4	0.08	71.7	6.7	2.5	2.6	0.22	3.6	3.8	Good	151207
RR155	RRS	LPreP	Sheep	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
RR156	RRS	LPreP	Sheep	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
RR158	RRS	LPreP	Sheep	Mandible	W	376.7	35.5	-20.7	-20.6	0.08	129.6	12.2	6.8	7.0	0.17	3.4	n/a	Good	151207
RR159	RRS	LPreP	Sheep	Mandible	W	188.7	17.5	-21.0	-20.9	0.08	62.1	5.7	4.5	4.7	0.20	3.5	n/a	Low N and/or C µg	151207
RR160	RRS	PreP	Sheep	Mandible	W	336.4	29.8	-20.2	-20.0	0.08	116.2	10.3	6.4	6.6	0.17	3.4	n/a	Good	151207
RR161	RRN	PreP	Sheep	Mandible	W	462.6	44.1	-19.4	-19.2	0.08	161.3	15.4	5.5	5.6	0.18	3.3	0.9	Good	160212
RR162	RRN	PreP	Sheep	Mandible	W	507.6	44.5	-20.6	-20.4	0.08	179.9	15.8	5.1	5.2	0.18	3.3	1.4	Good	160212
RR163	RRN	PreP	Sheep	Mandible	W	526.8	45.4	-20.8	-20.7	0.07	189.6	16.3	5.4	5.5	0.18	3.2	5.7	Good	160212B
RR164	RRN	PreP	Sheep	Mandible	W	446.4	43.3	-20.6	-20.4	0.08	151.2	14.7	5.2	5.4	0.18	3.4	0.5	Good	160212
RR165	RRN	PreP	Sheep	Mandible	W	500.0	45.0	-21.3	-21.1	0.07	176.0	15.9	4.9	5.0	0.18	3.3	1.9	Good	160212
RR166	RRN	PreP	Goat	Mandible	(U)	456.4	42.3	-20.1	-20.0	0.08	156.6	14.5	6.1	6.2	0.18	3.4	0.7	Good	160212B
RR167	RRN	PreP	Goat	Mandible	W	459.0	39.6	-20.7	-20.6	0.08	160.0	13.8	5.0	5.1	0.18	3.3	1.3	Good	160212

RR168	RRN	PreP	Goat	Mandible	W	469.8	42.7	-20.4	-20.2	0.08	165.0	15.0	5.9	6.0	0.18	3.3	1.3	Good	160212
RR169	RRS	NP	Sheep	Mandible	W	396.7	38.9	-21.2	-21.0	0.07	138.0	13.5	5.8	5.9	0.18	3.4	1.4	Good	160212
RR172	RRN	NP	Sheep	Mandible	(U)	477.0	45.9	-20.6	-20.4	0.08	172.7	16.6	5.1	5.2	0.18	3.2	11.4	Good	160212
RR173	RRN	NP	Goat	Mandible	(U)	505.4	44.3	-19.1	-18.9	0.08	183.2	16.1	2.8	2.9	0.20	3.2	6.4	Good	160212B
RR174	RRN	NP	Sheep	Mandible	W	474.1	43.9	-21.4	-21.2	0.07	164.2	15.2	4.7	4.8	0.18	3.4	1.7	Good	160212B
RR175	RRN	NP	Sheep	Mandible	(U)	542.8	47.2	-20.0	-19.8	0.08	198.1	17.2	3.9	4.0	0.19	3.2	12.7	Good	160212B
RR177	RRN	NP	Sheep	Mandible	(U)	527.6	45.9	-21.0	-20.8	0.07	187.2	16.3	7.1	7.2	0.18	3.3	2.8	Good	160212
RR178	RRN	NP	Goat	Mandible	U	509.4	45.1	-19.8	-19.7	0.08	178.8	15.8	8.1	8.2	0.19	3.3	2.1	Good	160212B
RR179	RRN	NP	Goat	Mandible	W	502.0	43.7	-19.7	-19.5	0.08	175.1	15.2	3.2	3.2	0.19	3.3	2.3	Good	160212B
RR180	RRN	NP	Goat	Mandible	(U)	470.9	43.6	-19.4	-19.2	0.08	167.2	15.5	4.8	4.9	0.18	3.3	3.7	Good	160212
RR182	RRN	NP	Sheep	Mandible	(U)	500.7	43.5	-20.5	-20.3	0.08	181.6	15.8	6.4	6.5	0.18	3.2	8.6	Good	160212
RR183	RRN	NP	Sheep	Mandible	W	482.7	45.5	-19.2	-19.0	0.08	174.6	16.5	5.7	5.8	0.18	3.2	11.1	Good	160212B
RR184	RRN	NP	Sheep	Mandible	W	473.0	41.9	-19.6	-19.4	0.08	170.3	15.1	7.4	7.5	0.18	3.2	9.2	Good	160212B
RR186	RRN	NP	Sheep	Mandible	W	489.7	43.3	-20.7	-20.5	0.08	175.2	15.5	5.9	6.0	0.18	3.3	3.5	Good	160212
RR188	RRN	FP	Goat	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
RR189	RRN	NP	Goat	Mandible	U	517.3	45.8	-19.9	-19.7	0.08	186.6	16.5	7.3	7.4	0.18	3.2	3.7	Good	n/a
RR190	RRS	PostP	Sheep	Mandible	W	429.9	42.6	-19.9	-19.7	0.08	150.5	14.9	6.9	7.0	0.18	3.3	1.6	Good	160212B
RR191	RRS	FP	Sheep	Mandible	W	455.3	44.6	-20.7	-20.5	0.08	162.5	15.9	5.0	5.1	0.18	3.3	3.3	Good	160212
RR193	RRS	NP	Sheep	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	PCP	n/a
RR194	HH	OP	Cattle	Humerus	W	499.3	44.2	-21.0	-20.8	0.07	178.7	15.8	4.5	4.5	0.19	3.3	2.6	Good	160212B
RR195	RRN	NP	Fallow deer	Humerus	W	506.2	44.8	-21.1	-20.9	0.07	182.6	16.2	5.0	5.1	0.18	3.2	10.7	Good	160212
RR196	RRN	NP	Fallow deer	Humerus	W	529.7	46.5	-21.7	-21.6	0.07	192.6	16.9	4.1	4.1	0.19	3.2	6.2	Good	160212B
RR197	RRN	NP	Fallow deer	Humerus	W	500.6	43.9	-20.8	-20.7	0.08	179.8	15.8	4.4	4.5	0.18	3.2	1.6	Good	160212
RR198	RRN	NP	Fallow deer	Tibia	W	476.6	44.1	-21.2	-21.0	0.07	167.7	15.5	5.6	5.7	0.18	3.3	3.0	Good	160212
RR199	RRS	FP	Fallow deer	Metatarsal	?	497.8	45.7	-20.8	-20.6	0.07	178.2	16.3	5.7	5.8	0.18	3.3	2.9	Good	160212B
RR200	RRN	NP	Fallow deer	Femur	W	497.4	46.1	-20.4	-20.3	0.08	179.0	16.6	4.9	4.8	0.18	3.2	5.7	Good	160210B
RR201	RRS	FP	Fallow deer	Tibia	W	489.9	43.4	-20.9	-20.8	0.08	179.2	15.9	6.2	6.2	0.17	3.2	11.2	Good	160210B
RR202	RRN	NP	Fallow deer	Radius	W	341.4	32.5	-21.1	-21.1	0.08	117.7	11.2	5.8	5.9	0.19	3.4	1.8	Good	151019C
RR203	RRN	NP	Fallow deer	Metacarpal	W	460.8	40.1	-20.9	-20.9	0.08	168.1	14.6	4.8	4.9	0.20	3.2	11.1	Good	151019C
WCH01	WCH	PreP	Cattle	Humerus	W	467.0	42.8	-20.0	-20.0	0.09	167.2	15.3	5.5	5.6	0.19	3.3	2.3	Good	151021A
WCH02	WCH	PreP	Cattle	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.6	PCP	n/a
WCH03	WCH	PreP	Cattle	Radius	W	121.7	11.3	-20.9	-21.0	0.14	42.7	4.0	6.2	6.2	0.19	3.3	1.4	Low N and/or C µg	151021B
WCH04	WCH	PreP	Cattle	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.2	PCP	n/a
WCH05	WCH	PreP	Cattle	Femur	?	340.2	29.3	-20.4	-20.5	0.14	123.2	10.6	4.9	4.8	0.19	3.2	3.6	Good	151021B
WCH06	WCH	PreP	Cattle	Metatarsal	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4.4	PCP	n/a
WCH07	WCH	PreP	Cattle	Metatarsal	W	336.4	31.7	-19.5	-19.5	0.09	120.9	11.4	7.5	7.5	0.19	3.2	5.3	Good	151021A
WCH08	WCH	PreP	Cattle	Humerus	W	388.9	39.3	-19.8	-19.8	0.09	137.9	13.9	6.8	6.8	0.19	3.3	1.2	Good	151021A
WCH09	WCH	PreP	Cattle	Metacarpal	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.3	PCP	n/a
WCH10	WCH	PreP	Pig	Humerus	U	360.1	32.7	-20.4	-20.4	0.09	129.3	11.8	6.2	6.2	0.19	3.2	7.6	Good	151021A
WCH11	WCH	PreP	Pig	Humerus	W	30.4	3.1	-25.8	-25.8	0.11	4.4	0.5	3.9	3.9	0.20	8.0	0.1	High C:N	151021A

WCH12	WCH	PreP	Pig	Humerus	W	191.6	19.0	-21.1	-21.1	0.09	66.5	6.6	3.4	3.4	0.21	3.4	2.4	Low N and/or C	151021A
WCH13	WCH	PreP	Pig	Radius	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.8	PCP	n/a
WCH14	WCH	PreP	Pig	Humerus	W	283.0	27.7	-20.7	-20.7	0.09	95.8	9.4	6.4	6.4	0.19	3.4	2.6	Good	151021A
WCH15	WCH	PreP	Pig	Tibia	W	454.6	42.5	-21.1	-21.1	0.09	157.8	14.7	4.1	4.1	0.20	3.4	0.7	Good	151021A
WCH16	WCH	PreP	Pig	Humerus	W	475.2	41.3	-20.8	-20.8	0.09	169.9	14.8	4.0	4.0	0.20	3.3	4.7	Good	151021A
WCH17	WCH	PreP	Pig	Radius	(W)	291.3	26.5	-20.2	-20.2	0.09	104.4	9.5	6.9	6.9	0.19	3.3	2.4	Good	151021A
WCH18	WCH	PreP	Sheep	Humerus	W	251.1	24.4	-21.1	-21.1	0.09	87.0	8.4	4.6	4.6	0.20	3.4	2.2	Good	151021A
WCH19	WCH	PreP	Sheep	Humerus	W	394.0	34.6	-20.6	-20.7	0.14	136.5	12.0	6.4	6.4	0.19	3.4	0.6	Good	151021B
WCH20	WCH	PreP	Sheep	Humerus	W	445.4	42.4	-20.5	-20.6	0.14	161.2	15.3	6.0	6.0	0.19	3.2	7.2	Good	151021B
WCH21	WCH	PreP	Sheep	Humerus	(U)	419.4	36.5	-20.6	-20.7	0.14	152.2	13.2	5.2	5.2	0.19	3.2	8.7	Good	151021B
WCH22	WCH	PreP	Sheep	Humerus	W	349.2	33.9	-20.1	-20.1	0.09	125.4	12.2	5.8	5.9	0.19	3.2	1.7	Good	151021A
WCH23	WCH	PreP	Sheep	Humerus	W	258.5	23.1	-21.0	-21.2	0.14	91.9	8.2	5.5	5.5	0.19	3.3	3.1	Good	151021B
WCH24	WCH	PreP	Sheep	Humerus	W	359.0	34.8	-20.2	-20.2	0.09	130.0	12.6	7.0	7.0	0.19	3.2	8.4	Good	151021A
WCH25	WCH	PreP	Sheep	Humerus	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	8.5	PCP	n/a
WCH26	WCH	PreP	Goat	Humerus	W	210.5	20.8	-20.4	-20.4	0.09	73.7	7.3	7.5	7.5	0.19	3.3	3.0	Good	151021A
WCH27	WCH	PreP	Goat	Humerus	W	431.4	43.1	-20.0	-20.0	0.09	152.2	15.2	5.9	5.9	0.19	3.3	3.7	Good	151021A
WCH28	WCH	PreP	Goat	Humerus	W	457.7	42.8	-20.0	-20.0	0.09	163.7	15.3	4.9	4.9	0.20	3.3	3.9	Good	151021A
WCH29	WCH	PreP	Goat	Humerus	W	209.9	18.9	-20.1	-20.1	0.09	73.5	6.6	4.8	4.9	0.20	3.3	3.2	Good	151021A
WCH30	WCH	PreP	Goat	Humerus	W	462.3	40.2	-19.8	-19.8	0.09	167.0	14.5	4.1	4.1	0.20	3.2	4.5	Good	151021A
WCH31	WCH	PreP	Goat	Humerus	W	396.3	37.0	-19.4	-19.5	0.14	144.8	13.5	9.5	9.5	0.21	3.2	3.2	Good	151021B
WCH32	WCH	PreP	Goat	Humerus	W	284.6	26.4	-19.7	-19.7	0.09	101.7	9.4	5.1	5.1	0.20	3.3	4.8	Good	151021A
WCH33	WCH	PreP	Goat	Humerus	W	441.9	41.7	-19.5	-19.4	0.07	158.0	14.9	6.0	6.2	0.16	3.3	9.5	Good	151207B
WCH34	WCH	PreP	Dog	Femur	?	224.8	19.7	-19.9	-19.8	0.07	74.3	6.5	2.3	2.4	0.20	3.5	2.3	Good	151207B
WCH38	WCH	PreP	Sheep	Mandible	(U)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.3	PCP	n/a
WCH40	WCH	PreP	Goat	Mandible	W	455.7	44.7	-20.2	-20.1	0.07	155.7	15.3	6.0	6.2	0.16	3.4	1.7	Good	151207B
WCH41	WCH	PreP	Goat	Mandible	W	25.6	2.2	-22.2	-22.1	0.06	5.6	0.5	2.9	3.0	0.19	5.4	1.5	High C:N	151207B
WCH42	WCH	PreP	Goat	Mandible	(U)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.7	PCP	n/a
WCH43	WCH	PreP	Goat	Mandible	W	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2.9	PCP	n/a
<b>Sample quality</b>																			
BAE=bad analytical environment																			
PCP=poor collagen preservation																			
<b>Weaning status</b>																			
<u>U=potentially un-weaned/recently weaned (unfused distal humerus/proximal radius; mandibular 1<sup>st</sup> molar unerupted, erupting or just in wear)</u>																			
<u>(U)=probably not un-weaned/recently weaned (fusing distal humerus/proximal radius; 1<sup>st</sup> mandibular molar in wear and 2<sup>nd</sup> unerupted)</u>																			
<u>W=weaned (fused distal humerus/proximal radius or later fusing element; mandibular 2<sup>nd</sup> molar erupting or in wear)</u>																			
<u>(W)=weaned (bone size/robusticity suggests adult)</u>																			
<u>?=weaning status unknown</u>																			



Table S4. Frequency of successful bone collagen samples by species (total counts exclude specimens that failed due to bad analytical environment or other run errors and were not subsequently re-run due to lack of extra collagen): (a) Neolithic and Bronze Age; (b) Bronze Age phases (major farmyard animals [MFA] only)

(a)	<i>Horse</i>		<i>Cattle</i>		<i>Pig</i>		<i>Sheep</i>		<i>Goat</i>		<i>Fallow deer</i>		<i>Dog</i>		<i>Badger</i>		<i>All</i>	
	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>
Neolithic	not present		43	25.6	78	52.6	137	65.0	68	70.6	not present		11	54.5	3	33.3	340	57.7
Bronze Age	1	100	47	72.3	51	80.4	104	87.5	79	89.9	16	100.0	5	100	2	100.0	305	85.6
<i>All</i>	<i>1</i>	<i>100</i>	<i>90</i>	<i>50.0</i>	<i>129</i>	<i>63.6</i>	<i>241</i>	<i>74.7</i>	<i>149</i>	<i>79.9</i>	<i>16</i>	<i>100.0</i>	<i>16</i>	<i>68.8</i>	<i>5</i>	<i>60.0</i>	<i>645</i>	<i>70.9</i>

(b)	<i>Cattle</i>		<i>Pig</i>		<i>Sheep</i>		<i>Goat</i>		<i>All MFA</i>	
	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>	<i>Total</i>	<i>% good</i>
Prepalatial	9	44.4	12	41.7	23	73.9	19	73.7	63	63.5
Late Prepalatial	7	71.4	6	66.7	14	78.6	8	87.5	35	77.1
Old Palace	3	100.0	6	100.0	10	80.0	4	75.0	23	87.0
New Palace	22	72.7	14	92.9	35	94.3	27	100.0	98	90.8
Final Palace	6	100.0	12	100.0	19	100.0	20	95.0	57	98.2
Postpalatial	not sampled		1	100.0	3	100.0	1	100.0	5	100.0

Table S5. Tukey post-hoc analysis of significant ANOVA results for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of animal bone collagen from Neolithic and Bronze Age Knossos (see Table 5); P-values > 0.05 are highlighted

Sheep $\delta^{15}\text{N}$									
	IN	EN	LN I	LN II	FN	PreP	LPreP	OP	NP
EN	0.9977								
LN I	<b>0.0056</b>	0.1266							
LN II	0.9843	1.0000	0.0524						
FN	0.6244	0.9960	0.0930	0.9971					
PreP	0.2645	0.8712	0.8530	0.8442	0.9922				
LPreP	0.1227	0.6209	0.9997	0.5584	0.8581	0.9997			
OP	<b>0.0006</b>	<b>0.0138</b>	0.8227	<b>0.0059</b>	<b>0.0127</b>	0.1894	0.6437		
NP	0.1534	0.7847	0.7094	0.7048	0.9626	1.0000	0.9995	0.1178	
FP	0.0565	0.4774	0.9987	0.3653	0.6701	0.9990	1.0000	0.5085	0.9978
Goat $\delta^{15}\text{N}$ (excluding unweaned)									
	LN I	LN II	FN	PreP	LPreP	NP			
LN II	0.9996								
FN	0.9965	0.8967							
PreP	0.9140	0.6212	0.9754						
LPreP	0.2509	0.4357	<b>0.0070</b>	<b>0.0027</b>					
NP	<b>0.0185</b>	<b>0.0447</b>	<b>0.0000</b>	<b>0.0000</b>	0.9968				
FP	0.2129	0.4087	<b>0.0002</b>	<b>0.0001</b>	0.9998	0.8153			
LN I $\delta^{13}\text{C}$			FN $\delta^{13}\text{C}$			PreP $\delta^{13}\text{C}$			
	pig	goat		pig	goat		goat	pig	
goat	<b>0.002</b>		goat	<b>0.002</b>		pig	<b>0.037</b>		
sheep	0.980	<b>0.001</b>	sheep	0.990	<b>0.0001</b>	sheep	<b>0.019</b>	0.816	
NP $\delta^{13}\text{C}$			FP $\delta^{13}\text{C}$						
	cattle	goat	pig		cattle	goat	pig		
goat	<b>0.003</b>			goat	0.388				
pig	0.528	0.250		pig	1.000	0.190			
sheep	0.949	<b>0.002</b>	0.721	sheep	0.990	<b>0.043</b>	0.980		
NP $\delta^{15}\text{N}$			FP $\delta^{15}\text{N}$						
	cattle	goat	pig		cattle	goat	pig		
goat	<b>0.000</b>			goat	0.19				
pig	0.763	<b>0.000</b>		pig	0.53	<b>0.00</b>			
sheep	0.997	<b>0.000</b>	0.787	sheep	0.97	0.11	0.09		

Table S6. Summary statistics for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of animal bone collagen from Neolithic and Bronze Age Knossos compared with Neolithic Halai, Makriyalos and Kouphovouno and with Bronze Age Archontiko, Toumba Thessalonikis and Mycenae  
SD = one standard deviation ( $1\sigma$ )

		$\delta^{13}\text{C}$				$\delta^{15}\text{N}$				
		Min	Max	Average	SD	Min	Max	Average	SD	N
Halai Neolithic	Cattle	-21.2	-13.5	-18.4	2.4	4.6	7.4	6.3	0.8	9
	Sheep	-21.3	-16.2	-19.8	1.1	3.4	8.2	5.9	1	19
	Goat	-20.8	-18.7	-20.1	0.6	3	6.5	5.6	0.9	14
	Pig	-20.4	-19.3	-19.8	0.4	5.6	8.1	7	0.8	9
Makriyalos LN	Cattle	-21.3	-13.6	-16.8	2.2	3.1	6.5	4.9	1.0	22
	Sheep	-21.8	-17.2	-19.4	1.2	3.6	7.5	5.1	1.0	22
	Goat	-20.9	-18.3	-19.8	0.6	2.4	6.4	4.3	1.0	27
	Pig	-21.4	-20.2	-20.7	0.3	4.2	6.2	5.2	0.8	13
Kouphovouno MN & LN	Cattle	-21.1	-17.7	-20.4	0.9	2.7	8.4	4.8	1.2	15
	Sheep	-21.1	-19.6	-20.5	0.4	4.2	6.3	5.1	0.6	12
	Goat	-20.5	-19.7	-20.1	0.2	3.3	6.0	4.5	0.9	7
	Pig	-21.1	-19.1	-20.3	0.4	4.4	7.5	5.9	0.9	23
Archontiko late EBA-LBA	Cattle	-23.1	-11.4	-17.6	2.9	3.3	11.1	6.3	1.7	36
	Sheep	-21.4	-11.7	-19.4	2.1	3.6	9.0	5.8	1.2	19
	Pig	-21.5	-19.0	-20.3	0.6	4.3	8.9	6.7	1.2	38
Toumba Thessalonikis LBA	Cattle	-21.0	-10.1	-15.6	3.5	3.6	7.7	5.4	1.3	13
	Sheep	-21.0	-14.2	-18.9	1.2	5.3	8.8	6.8	1.1	36
	Goat	-20.6	-18.8	-19.5	0.4	3.8	8.8	5.3	1.2	33
	Pig	-20.9	-16.3	-19.6	1.0	5.3	9.9	7.6	1.0	26
Mycenae LBA	Cattle	-21	-18.8	-20.3	0.6	3.4	10	5.9	1.9	14
	Sheep	-21.7	-19.3	-20.6	0.5	3.8	8.3	5.3	1.1	32
	Goat	-21.8	-18.9	-20.6	0.7	3.2	10.7	5	1.6	22
	Pig	-21.2	-18.2	-20.2	0.8	3.9	10.4	6.4	1.9	15
Knossos Neolithic	Cattle	-21.1	-19.4	-20.5	0.5	4.5	6.9	5.2	0.7	11
	Sheep	-22.1	-19.5	-20.7	0.4	3.7	8.7	5.5	0.9	89
	Goat	-20.9	-16.7	-20.0	0.7	3.7	7.5	5.5	0.8	48
	Pig	-21.5	-19.4	-20.6	0.5	3.1	7.8	5.7	1.2	41
Knossos BA	Cattle	-21.3	-18.6	-20.5	0.6	3.6	7.5	5.3	0.9	34
	Sheep	-21.9	-17.4	-20.5	0.7	2.6	7.7	5.2	1.0	91
	Goat	-21.5	-16.2	-19.8	0.7	1.4	9.4	4.6	1.4	71
	Pig	-21.3	-18.9	-20.4	0.6	2.9	8.3	5.5	1.3	41

Table S7. Estimated ranges of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for potential categories of forage at Neolithic-Bronze Age Knossos

<i>Category of forage</i>	<i>Estimated ranges of <math>\delta^{13}\text{C}</math> and <math>\delta^{15}\text{N}</math> values</i>																														
a. Neolithic and Bronze Age C <sub>3</sub> cereal and pulse grain fodder	68% and 95% confidence ellipses estimated from $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of cereal and pulse grains from Neolithic and Bronze Age Knossos, respectively (see Table S1)																														
b. Neolithic and Bronze Age cereal/pulse chaff fodder	-2.5‰ (cereal $\delta^{13}\text{C}$ )/-1.5‰ (pulse $\delta^{13}\text{C}$ ) and -2.4‰ (cereal $\delta^{15}\text{N}$ )/-0.5‰ (pulse $\delta^{15}\text{N}$ ) offsets from 68% and 95% confidence ellipses estimated for cereal and pulse grains from Neolithic and Bronze Age Knossos, respectively (above, a)																														
c. Neolithic and Bronze Age stubble/fallow(/young cereal) pasture	-1.5‰ ( $\delta^{13}\text{C}$ ) and -1.4‰ ( $\delta^{15}\text{N}$ ) offsets from 68% and 95% confidence ellipses estimated for <i>cereal</i> grains from Neolithic and Bronze Age Knossos, respectively																														
d. Neolithic-Bronze Age rough graze and browse on lowland central Crete	95% confidence ellipses estimated from mean wet- and dry-season $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for annuals/forbs and shrubs/trees, respectively, at 500 mm mean annual rainfall extrapolated from Hartman (2008, appx A) using a linear regression model; reported $\delta^{13}\text{C}$ values corrected by +1.8‰ to allow for changing atmospheric $\delta^{13}\text{C}$ values:  <div style="text-align: center;"><i>95% confidence interval</i></div> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th><i>Annuals/forbs</i></th> <th><i>Mean (‰)</i></th> <th><i>Lower CI</i></th> <th><i>Upper CI</i></th> <th><i>Difference from mean</i></th> </tr> </thead> <tbody> <tr> <td><math>\delta^{13}\text{C}</math> (‰)</td> <td>-27.69</td> <td>-28.40</td> <td>-26.99</td> <td>0.71</td> </tr> <tr> <td><math>\delta^{15}\text{N}</math> (‰)</td> <td>-0.73</td> <td>-1.66</td> <td>0.19</td> <td>0.92</td> </tr> </tbody> </table> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th><i>Shrubs/trees</i></th> <th><i>Mean (‰)</i></th> <th><i>Lower CI</i></th> <th><i>Upper CI</i></th> <th><i>Difference from mean</i></th> </tr> </thead> <tbody> <tr> <td><math>\delta^{13}\text{C}</math> (‰)</td> <td>-26.38</td> <td>-26.91</td> <td>-25.86</td> <td>0.53</td> </tr> <tr> <td><math>\delta^{15}\text{N}</math> (‰)</td> <td>-1.36</td> <td>-2.37</td> <td>-0.36</td> <td>1.01</td> </tr> </tbody> </table>	<i>Annuals/forbs</i>	<i>Mean (‰)</i>	<i>Lower CI</i>	<i>Upper CI</i>	<i>Difference from mean</i>	$\delta^{13}\text{C}$ (‰)	-27.69	-28.40	-26.99	0.71	$\delta^{15}\text{N}$ (‰)	-0.73	-1.66	0.19	0.92	<i>Shrubs/trees</i>	<i>Mean (‰)</i>	<i>Lower CI</i>	<i>Upper CI</i>	<i>Difference from mean</i>	$\delta^{13}\text{C}$ (‰)	-26.38	-26.91	-25.86	0.53	$\delta^{15}\text{N}$ (‰)	-1.36	-2.37	-0.36	1.01
<i>Annuals/forbs</i>	<i>Mean (‰)</i>	<i>Lower CI</i>	<i>Upper CI</i>	<i>Difference from mean</i>																											
$\delta^{13}\text{C}$ (‰)	-27.69	-28.40	-26.99	0.71																											
$\delta^{15}\text{N}$ (‰)	-0.73	-1.66	0.19	0.92																											
<i>Shrubs/trees</i>	<i>Mean (‰)</i>	<i>Lower CI</i>	<i>Upper CI</i>	<i>Difference from mean</i>																											
$\delta^{13}\text{C}$ (‰)	-26.38	-26.91	-25.86	0.53																											
$\delta^{15}\text{N}$ (‰)	-1.36	-2.37	-0.36	1.01																											
e. Neolithic-Bronze Age summer rough graze on upland central Crete	+1.5‰ ( $\delta^{13}\text{C}$ ) and -1.5‰ ( $\delta^{15}\text{N}$ ) offsets from 95% confidence ellipse estimated for lowland rough graze on central Crete (above, d)																														
f. Neolithic-Bronze Age lowland autumn-winter pannage	+3‰ ( $\delta^{13}\text{C}$ ) and +2‰ ( $\delta^{15}\text{N}$ ) offsets from 95% confidence ellipse estimated for lowland rough browse on central Crete (above, d)																														
g. Neolithic-Bronze Age lowland C <sub>4</sub> grain fodder	68% and 95% confidence ellipses estimated from $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of common millet grains from Bronze Age <a href="#">Archontiko</a> and <a href="#">Toumba Thessalonikis</a> (after Nitsch <i>et al.</i> 2017, 116-17 figs 4-5)																														

Table S8. The mean and standard deviation of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of standards in each carbon and nitrogen isotope run										
Plant remains										
Run file	Alanine	Alanine sd	CAFF	CAFF sd	C6	C6 sd	C7	C7 sd	N2	N2 sd
$\delta^{13}\text{C}$ (‰)										
150206B	-26.91	0.09	n/a	n/a	-10.18	0.06	-31.70	0.13	n/a	n/a
150207A	-26.83	0.54	n/a	n/a	-10.05	0.37	-31.42	0.44	n/a	n/a
151208	-27.11	0.05	n/a	n/a	-10.37	0.08	-31.79	0.09	n/a	n/a
$\delta^{15}\text{N}$ (‰)										
150324B	-1.57	0.06	-3.11	0.06	n/a	n/a	n/a	n/a	20.54	0.08
150327B	-1.57	0.17	-3.17	0.19	n/a	n/a	n/a	n/a	20.35	0.28
151209B	-1.59	0.21	1.28	0.18	n/a	n/a	n/a	n/a	20.53	0.14
Animal bone collagen										
Run file	Alanine	Alanine sd	CAFF	CAFF sd	SEAL	SEAL sd				
$\delta^{13}\text{C}$ (‰)										
150209A	-26.85	0.12	-34.62	0.18	-13.26	0.19				
150209B	-26.93	0.10	-34.69	0.09	-13.23	0.07				
151016	-27.13	0.02	-27.71	0.02	-13.38	0.08				
151019	-27.12	0.02	-27.74	0.04	-13.44	0.03				
151019B	-27.11	0.04	-27.70	0.08	-13.37	0.03				
151019C	-27.13	0.05	-27.71	0.02	-13.38	0.03				
151020A	-27.10	0.03	-27.78	0.12	-13.51	0.11				
151020B	-27.12	0.07	-27.75	0.04	-13.38	0.10				
151020C	-27.20	0.06	-27.72	0.02	-13.47	0.09				
151021A	-27.08	0.04	-27.68	0.10	-13.38	0.03				
151021B	-27.10	0.02	-27.59	0.20	-13.22	0.14				
151207	-27.11	0.05	-27.71	0.06	-12.38	0.09				
151207B	-27.13	0.05	-27.70	0.03	-12.39	0.05				
160210B	-27.08	0.05	-27.68	0.04	-12.36	0.04				
160211	-27.13	0.11	-27.71	0.02	-12.36	0.05				
160212	-27.10	0.03	-27.72	0.04	-12.44	0.08				
160212B	-27.08	0.03	-27.71	0.03	-12.41	0.06				
$\delta^{15}\text{N}$ (‰)										
150209A	-1.69	0.20	-2.66	0.28	16.89	0.21				
150209B	-1.59	0.15	-2.65	0.09	16.97	0.25				
151016	-1.60	0.05	0.89	0.17	17.39	0.11				
151019	-1.56	0.03	0.85	0.06	17.27	0.05				
151019B	-1.69	0.34	0.83	0.06	17.31	0.10				
151019C	-1.52	0.07	0.87	0.09	17.35	0.08				
151020A	-1.56	0.07	0.97	0.15	17.45	0.19				
151020B	-1.59	0.06	0.82	0.06	17.33	0.04				
151020C	-1.54	0.06	0.87	0.04	17.31	0.09				
151021A	-1.52	0.06	0.95	0.11	17.40	0.07				
151021B	-1.53	0.05	1.04	0.04	17.41	0.20				
151207	-1.52	0.08	0.92	0.11	16.25	0.08				
151207B	-1.47	0.06	0.93	0.05	16.15	0.12				
160210B	-1.53	0.05	1.14	0.05	16.35	0.03				
160211	-1.47	0.07	1.18	0.03	16.33	0.03				
160212	-1.53	0.06	0.93	0.02	16.40	0.05				
160212B	-1.56	0.06	1.00	0.06	16.33	0.07				