**[For SUPPLEMENTARY MATERIAL]**

**Early animal management in northern Europe: new multi-proxy evidence from Swifterbant, the Netherlands**

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**Detailed materials & methods**

At S3, all bone fragments larger than 10mm were collected by hand and the soil was wet-sieved (3mm mesh) (Zeiler 1997; Prummel *et al.* 2009: 33). The postcranial suid remains were fewer and highly fragmented compared to the dental elements; for cattle, it was the opposite.

Seven *Bos* specimens from the neighbouring S4 were also analysed as part of the stable isotope analysis. Additionally, the stable isotope data for three specimens (two cattle and one caprine), were provided by ADC Archeoprojecten. These specimens were collected by hand during excavations across the Swifterbant area, carried out as part of the development-led ‘Windplan Blauw’ archaeology project. The coordinates of one Windplan Blauw sample, number 25, are unknown.

The sites S2, S3 and S4 were located in a freshwater wetland area that consisted of a system of small rivers with river banks (Figure S15). The Windplan Blauw excavations were also carried out in this area. The reconstruction of the river system and the major landscape units (Figure 1) are based on extensive excavation and coring data from this region (Dresscher & Raemaekers 2010; Schepers 2014; Raemaekers & de Roever 2020; Schepers & Woltinge 2020).

*Biometric analysis*

Logarithmic Size Index (LSI) analysis of metric data is one of the most applied methods to investigate domestication (Zeder 2006). It alleviates the problem of small sample sizes and recent studies continue to show that it is a better method than using direct assessment of single measurements (Wolfhagen 2020). The method compares the logarithm of recorded measurements to the same measurements of a ‘standard’ (Meadow 1999). Specimens that are smaller than the standard will scale negatively while specimens that are larger will scale positively, thereby providing insight into the size of the site’s suids and cattle and their possible domestic status.

We measured all measurable *Sus* teeth and postcranial elements and *Bos* postcranial elements from S3 following published standards (Von den Driesch 1976; Payne & Bull 1988; Albarella & Payne 2005; Jones 2007). The LSI analysis was carried out following Meadow (1999) (base = 10). In the case of an associated left and right element, the left element was excluded from analysis. Unfused postcranial elements and not (fully) erupted teeth are shown in Figures S3–5 but excluded from further analyses. The measurements were taken as part of a study by Kooistra (2022).

For the *Sus* postcranial analysis, we used a wild boar standard (Hongo & Meadow 2000—a female wild boar from Eastern Turkey). Scapula measurements were excluded to eliminate possible age bias (Albarella & Payne 2005; Zeder & Lemoine 2020). None of the astragali were light and porous, indicating a juvenile individual and therefore did not need to be excluded (Albarella & Payne 2005: 597).

For the *Bos* postcranial analysis, we used the aurochs standard established by Degerbøl and Fredskild (1970) and republished (with one amended measurement) in Grigson (1989—the Ullerslev specimen, a Mesolithic female aurochs). LSI values represent the average LSI of all measurements on one element, excluding length measurements except in the case of astragali and calcanea, following Meadow (1999) and Albarella and Payne (2005).

For the *Sus* dental analysis, we used the wild boar standard established by Payne and Bull (1988—the mean of a wild boar population). LSI values were calculated per tooth and represent the average LSI of the width measurements on one tooth; length measurements are excluded and upper and lower teeth are analysed separately, following Zeder and Lemoine (2020) and Meadow (1999).

Statistical analyses were carried out using IBM SPSS Statistics 28. No extreme outliers were identified in the *Sus* or *Bos* dataset.

*Age estimation*

Harvesting profiles can provide insight into hunting practices and potential herd management based on the survivorship of specific age classes (Magnell 2005; Albarella *et al.* 2006). Cattle tooth wear was recorded following Grant (1982) and wear stages and age classes following Legge (1992) (Table S5). Loose M1/M2s were identified where possible following the method of Beasley *et al.* (1993) based on the length of the cervical (CervL) and the width of the anterior (WA) compared to known M1 and M2 specimens from S3 and the Schipluiden data as a reference size (Kamjan *et al.* 2020) (Figure S8). Cattle postcranial fusion data were taken from (Zeiler 1997), which was calculated following Habermehl (1975) (Table S6).

We recorded suid tooth wear and tooth eruption and calculated survivorship following Lemoine *et al.* (2014) (System A) (Tables S7 & 8). In the case of an associated left and right side of a mandible or maxilla, tooth wear was scored for the most complete side or, in the case of a tie, for the right side. When possible, age class B in Lemoine *et al*.'s System A was broken down into age groups 3–5 months and 6–8 months (Lemoine *et al*.'s Specific System age classes 2 and 3) based on tooth wear and eruption state of the dP4 and M1 to allow for more detail on number of unweaned vs weaned piglets. Postcranial fusion and survivorship was carried out following Zeder *et al.* (2015)(Table S9)*.*

*Stable isotope analysis*

A total of 73 bone samples and 18 dentine samples was selected, which included suids, cattle, and baseline animals. For one individual (EDAN0376), we sampled the mandible bone and tooth dentine to test whether there would be a difference between bone and dentine values.

Pretreatment and collagen extraction was performed following a modified Longin (1971) protocol at the Centre for Isotope Research, University of Groningen (Dee *et al.* 2020). Briefly, the samples were first demineralised in an HCl (4% w/vol) solution, replenished several times over 24 hours. This was followed by NaOH (1% w/vol) to remove humic acids, and then a final HCl (4% w/vol) treatment to eliminate any CO2 absorbed during the base phase. Each step was followed by a triplicate rinse in deionised and decarbonised water. The samples were then denatured to gelatin in deionised and decarbonised water (pH 3, 80°C, 18 hr) and dried.

For the first 66 samples, approximately 5–6mg aliquots of extracted collagen were weighed out per sample. Samples yielding less than 0.5% collagen were rejected for quality control; this applied to nine samples. The δ13C and δ15N values were obtained via combustion in an elemental analyser (EA, Elementar Vario Isotope Cube) coupled to an Isotope Ratio Mass Spectrometer (IRMS, IsoPrime 100).

Due to instrument availability, for the remaining 25 samples, approximately 1mg aliquots of extracted collagen were weighed out per sample. These were combusted in another EA (PyroCube) coupled to another IRMS (PrecisION). Again, samples yielding less than 0.5% collagen were rejected for quality control; this applied to one sample.

The C:N range of 2.9–3.6 from DeNiro (1985) is often cited as acceptable for collagen purity, but the CIO prefers to investigate results if they fall outside 3.1–3.3 (Dee *et al.* 2020), and is moving to rejection for all samples outside 2.9–3.5. All results fell within this range. For quality control, each pretreatment batch included a secondary standard, with known isotope ratios, and a duplicate. The δ13C and δ15N data were obtained at the following 1σ precisions: δ13C = 0.15‰ and δ15N = 0.3‰. For one sample (EDAN0160), the measurement of the δ15N values failed in the IRMS.

Two samples were radiocarbon dated. The 5–6 mg of collagen from each sample were combusted in an EA (Elemental Vario Isotope Cube) coupled to an IRMS (IsoPrime 100) with an automated cryogenic system which traps the CO2 into sealable glass vessels. This combination allows for δ13C and δ15N measurements on all samples submitted for radiocarbon dating. The trapped CO2 is then graphitized over an iron catalyst in a stoichiometric excess of H2. Finally, the graphite is pressed into Al cathodes and transferred to the MICADAS mass spectrometer (Ionplus AG, 200kV) for radioisotope analysis.

The four bone samples from the Windplan Blauw project were also radiocarbon dated at the Centre for Isotope Research following the same protocol, upon which δ13C and δ15N values were obtained.

We submitted six of the collagen samples (EDAN0286, 352, 353, 357, 373 and 349) for identification via Zooarchaeology by Mass Spectrometry (ZooMS) at the BioArch laboratory at the University of York, which used the protocol outlined in Dierickx *et al.* (2022).

*Vegetation analysis*

Extensive archaeobotanical analyses have been carried out on multiple sites in the Swifterbant area (Casparie *et al*. 1977; Van Zeist & Palfenier-Vegter 1981; Raemaekers *et al*. 2014; Schepers & Bottema-Mac Gillavry 2020). We re-examined previous phytosociological vegetation analyses (Schepers *et al.* 2013). Phytosociology is the study of plant communities. More than using individual plants would do, it allows for the understanding of vegetation on a landscape ecological level. Using palaeoassocia (Schepers *et al*. 2013), the data collected for the previous studies were split into overlapping species groups, which were subsequently assigned to the most similar present-day plant communities (Schepers 2014). The plant communities (syntaxa) thus identified are inspected more closely for the nutrient availability generally associated with them, using SynBioSys (Hennekens *et al*. 2010). We look at both the nutrient values as calculated for these syntaxa using Ellenberg nutrient values for vascular plants (Ellenberg *et al*. 1991), as well as the nitrogen content measured in soils associated with plant species (Wamelink *et al*. 2005). We chose to focus on the most frequently identified syntaxa identified for the S3 and S4 sites. By doing so, we obtain a more nuanced view of the expected variation in nutrient availability in the region.

**Detailed results**

*Size*

The *Bos* postcranial elements scale small on the LSI scale with a mean of -0.081 and show little deviation (Figures 3a, S1 & S2). There is one exception: a specimen (910083/EDAN0263) that is larger than the standard Mesolithic female aurochs and was also identified as an aurochs by Zeiler (1997). One *Bos* M3 (9910142/EDAN0380) stands out as being an exceptionally large M3 and may be an aurochs.

The S3 *Bos* are significantly smaller than the (i) Mesolithic aurochs and *Bos* sp.from Ertebølle culture sites (Independent Samples T-Test, p = <0.001; Table S11-13), (ii) *Bos* sp. from the partly contemporary (4800–3800 BC) Swifterbant Culture site at Bazel, Belgium (Mann-Whitney U Test, p = 0.027), and (iii) primarily domestic cattle bones from Linearbandkeramik culture sites (Mann-Whitney U Test, p = <0.001). They are significantly larger than the cattle from Schipluiden (Mann-Whitney U Test, p = 0.008).

The *Sus* dental elements scale slightly small with a mean of -0.03 (lower teeth) and -0.046 (upper teeth) (Figures 3b & S3–7). They are significantly smaller than the Mesolithic wild boar specimens from Polderweg 1 (lower teeth: Independent Samples T-Test, p = <0.001; upper teeth: Mann-Whitney U Test, p = <0.001) and De Bruin 2 (lower: Independent Samples T-Test, p = <0.001; no upper) (Table S14). There is no significant difference with the Mesolithic wild boar from De Bruin 1 (lower: Independent Samples T-Test, p = 0.479; no upper). They are significantly larger than the Neolithic pigs from Durrington Walls (lower: Independent Samples T-Test, p = <0.001; upper: Mann-Whitney U Test, p = <0.001).

The postcranial elements also scale small (mean -0.024). They are significantly smaller than Polderweg 1 and De Bruin 2 (Independent Samples T-Test, p = <0.001, p = 0.002, respectively). They are significantly larger than Durrington Walls (Independent Samples T-Test, p = <0.001). There is no significant difference with De Bruin 1, De Bruin 4, or Schipluiden (Independent Samples T-Test, p = 0.391, p = 0.577, p = 0.458, respectively). There is one specimen that scales particularly large (a humerus, LSI of 0.061), which may be a wild boar.

*Mortality profile*

For the *Bos,* other than the young calves (<6 months), all ages are represented. The dentition-based profile presents a majority of adults in the assemblage, where most are between six and eight years old (n = 6), followed by three- to six-year-olds (n = 4) (Figure 3a, Table S6). One individual is between six and ten years old. There are no individuals younger than six months. The long bones reveal comparable results, whereby the majority of specimens are aged 24 to 30 months or older (n = 12) and there are none younger than seven months (Table S7). The assemblage yielded one fetal metatarsus (Zeiler 1997: 51). The results contrast with Schipluiden, where young cattle are more strongly represented.

The *Sus* dentition-based profile shows an emphasis on individuals between eight and twelve months old (n = 6) and 18 to 52 months (n = 7.5) (Table S9). Survivorship declines steadily through the age classes with the sharpest drop after 52 months old (Figure 3b). The survivorship compares closely with that of Polderweg, while it shows a higher survivorship of young suids than at Durrington Walls. When loose teeth and maxilla are included per Lemoine *et al.* (2014), the assemblage also presents a high number of suids aged three to five months olds (n = 24.5), followed by the six to eight month olds (n = 19.5) (Table S9). There are several individuals one month old or younger and two older than 96 months. Among the postcranial elements, the majority of specimens are aged seven to eight months (n = 4) (Table S10). There are no specimens younger than seven months and none older than five years.

*ZooMS*

Using ZooMS, individual EDAN0353 (initially identified as a caprine) was identified as a *Bos* sp., individual EDAN 0286 (initially identified as a *Bos* sp.) was identified as a Cervidae (elk, red deer or roe deer), individuals EDAN0352, 357, and 373 (initially identified as caprines) were identified as sheep (*Ovis aries*), and EDAN0349 (initially identified as an otter) was identified as a badger (*Meles meles*) (Table S17).

*Diet and environment*

The stable isotope analysis reveals clear distinctions within the δ13C andδ15N values of the sampled specimens (Table S15, Figure 5). The *Bos* specimens appear to form two groups in terms of both δ13C andδ15N values. Using these values, we performed a hierarchical agglomerative cluster analysis using Ward’s linkage. The results present two strong clusters (Figures S9 & S10). Cluster 1 consists of *Bos* with very elevatedδ15N values (mean +11.6‰). They are much higher than the Cervidae (mean +5.4‰), higher even than the otter and badger, and in same range as the dog and the humans. This cluster also has slightly elevated δ13C values (mean -21.1‰) compared to the Cervidae (-22.1‰). The caprines, of which three were identified as sheep (*Ovis aries*) using ZooMS, exhibit similar values to Cluster 1. The *Bos* from Swifterbant Windplan Blauw all fall within Cluster 1 whereas of the S4 samples, six fall within Cluster 1 and one within Cluster 2. Cluster 1 exhibits even higher δ15N values than the coastal grazing cattle and cervidae at Schipluiden (Figure S10).

Cluster 2 has more depleted δ13C values (mean -23.1‰) than the Cervidae, but the δ15N values (mean +5.6‰) are within the wild herbivore range. This Cluster has δ13C and δ15N values comparable to the cattle from Hardinxveld and δ13C values that are more depleted than the Schipluiden cattle. The caprine data from Windplan Blauw are more comparable to the Cluster 2 cattle than the S3 sheep.

The two clusters are significantly different from one another in both their δ13C values (Independent Samples T-Test, p = <0.001) and theirδ15N values (Independent Samples T-Test, p = <0.001) (Table S16). Each cluster contains specimens represented by different skeletal elements, including cranial and postcranial. It is therefore possible that some correspond to the same individual. However, based on biometrics, fusion state and stable isotope values it is possible to discern at least several individuals in each cluster.

The large, likely aurochs, specimen (EDAN0263) sits in Cluster 2. The rest of the measurable specimens all scale small in the LSI analysis (mean -0.081) and are divided across Clusters 1 and 2, indicating no link between size and stable isotope values (Figure S11).

There appears to be no difference between the δ13C andδ15N values of bone and dentine (Figure S12). Bone and dentine samples fall within both clusters and the bone and dentine results of EDAN0376 are very similar.

The *Sus* specimens exhibit an almost equally wide range of δ13C values (between -22.5‰ and -19.6‰) andδ15N (between +4.5‰ and +11.9‰) but with less clustering (Figure S13). The *Sus* δ13C values are comparable to those of the wild boar from Hardinxveld and slightly elevated compared to the S3 wild herbivores. They present overall more elevated δ15N values (mean +7.9‰) than the Hardinxveld wild boar (mean +5.3‰) and the S3 wild herbivores. Two individuals (EDAN0266 and EDAN0162) have particularly elevated δ15N values of +11.9‰ compared to the rest of the *Sus*; they fall within the same range as the *Bos* Cluster 1 and are more elevated than the dog. EDAN0162 could potentially be a suckling piglet as it is between 1 and 5 months old; EDAN0266 is, however, an adult (18 to 96 months old). This specimen also scales small in the LSI analysis (-0.064). Other than these specimens, there is no discernible correlation between size (LSI value) and δ13C andδ15N values (Figure S14).



Figure S1. Metrics of each Bos postcranial element on a Logarithmic Size Index scale, labelled by specimen number.

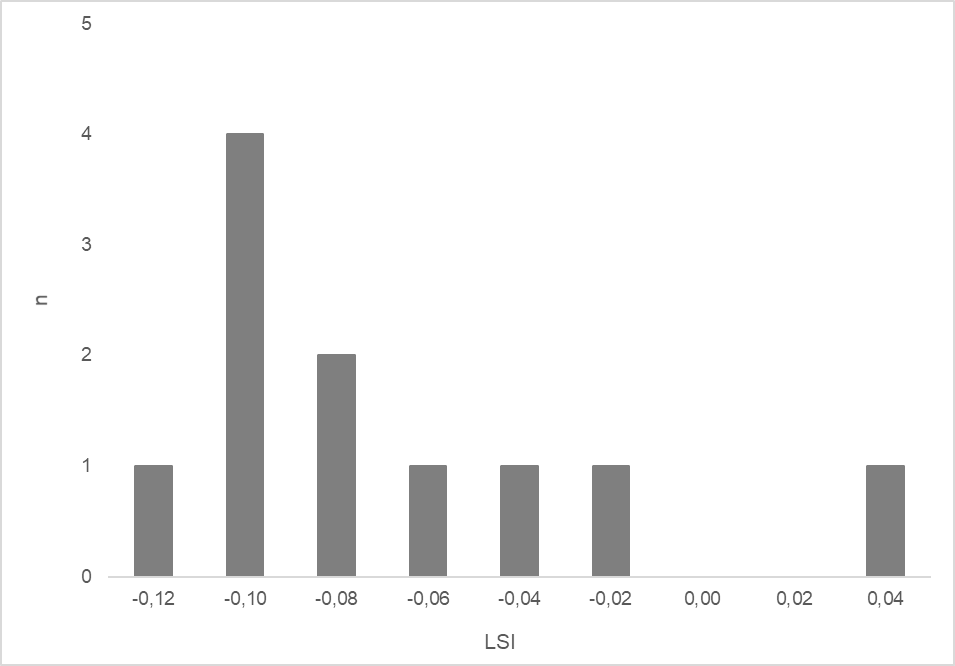


Figure S2. Histogram of Logarithmic Size Index (LSI) analysis of Bos postcranial elements.

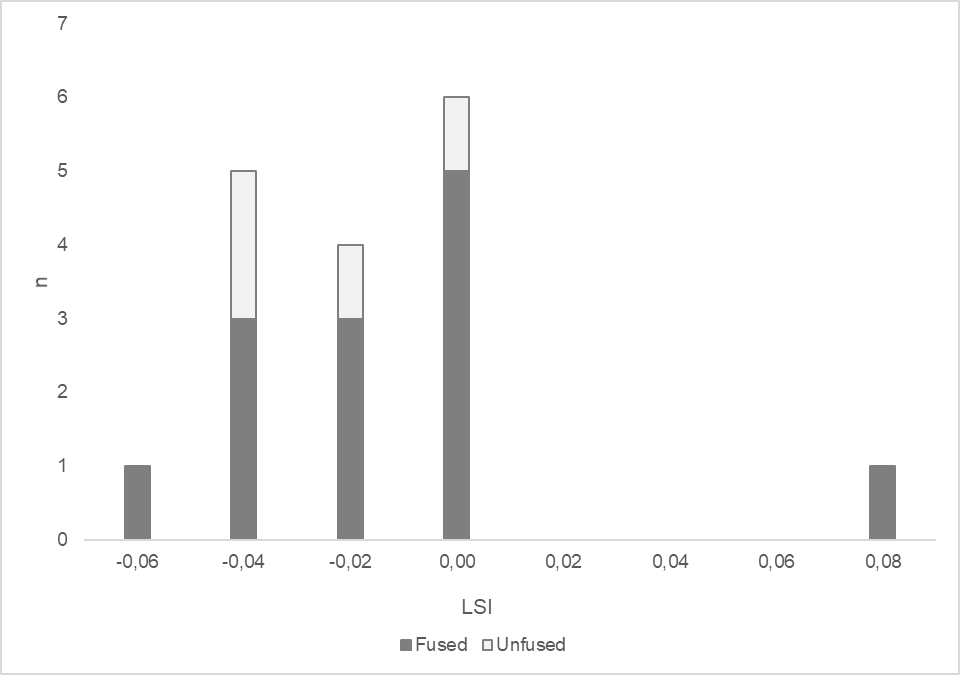


Figure S3. Histogram of Logarithmic Size Index (LSI) analysis of Sus postcranial elements.

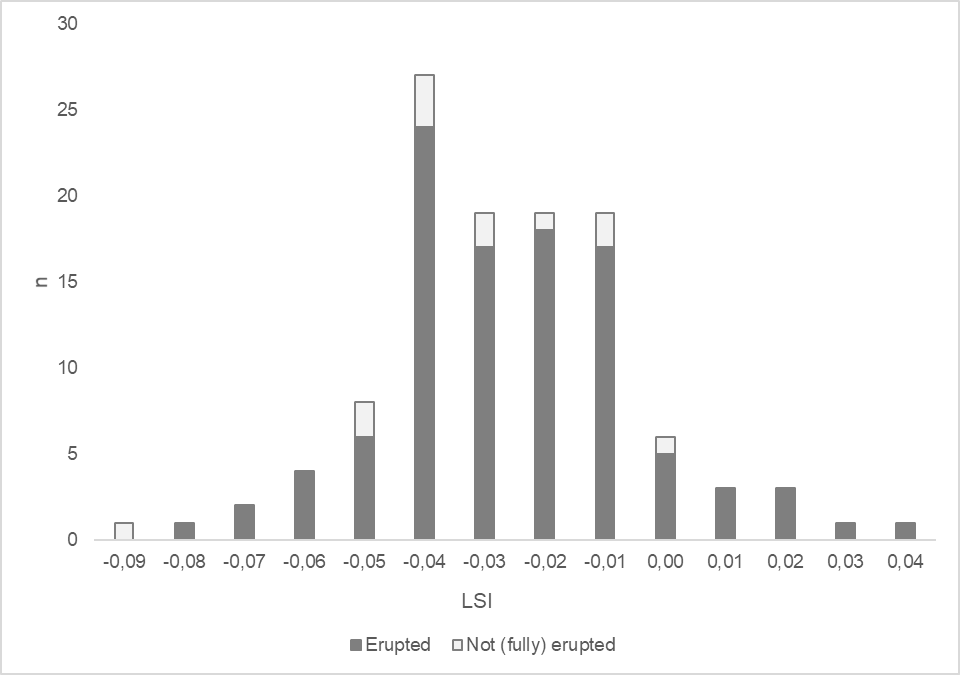


Figure S4. Histogram of Logarithmic Size Index (LSI) analysis of Sus lower teeth breadths.

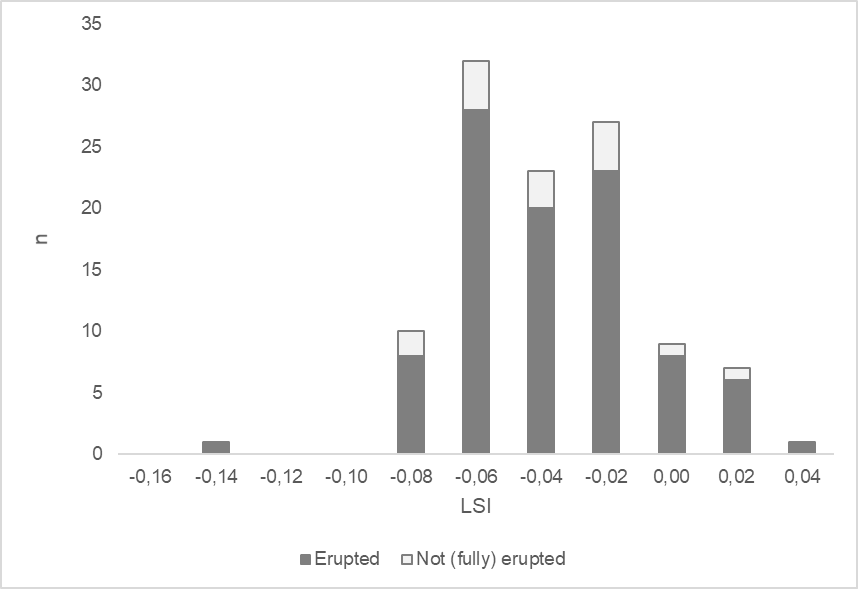


Figure S5. Histogram of Logarithmic Size Index (LSI) analysis of Sus upper teeth breadths.



Figure S6. Boxplot of Logarithmic Size Index (LSI) analysis of Sus upper teeth breadths compared to Polderweg (Brusgaard et al. 2022) and Durrington Walls (Albarella & Payne 2005).

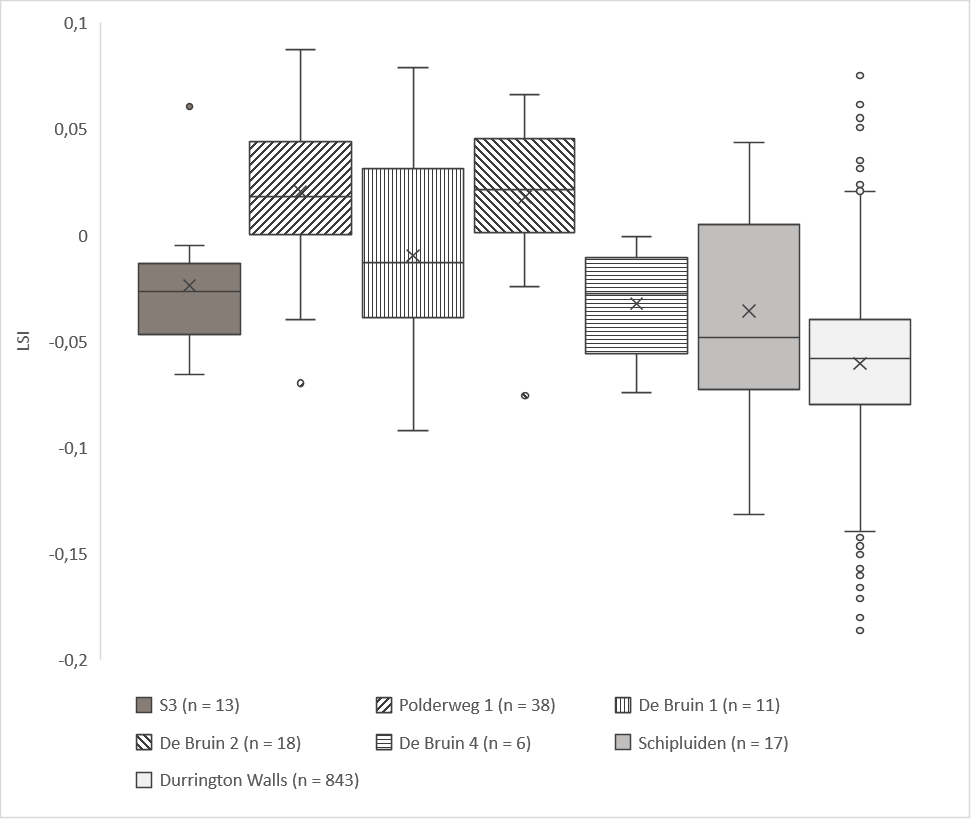
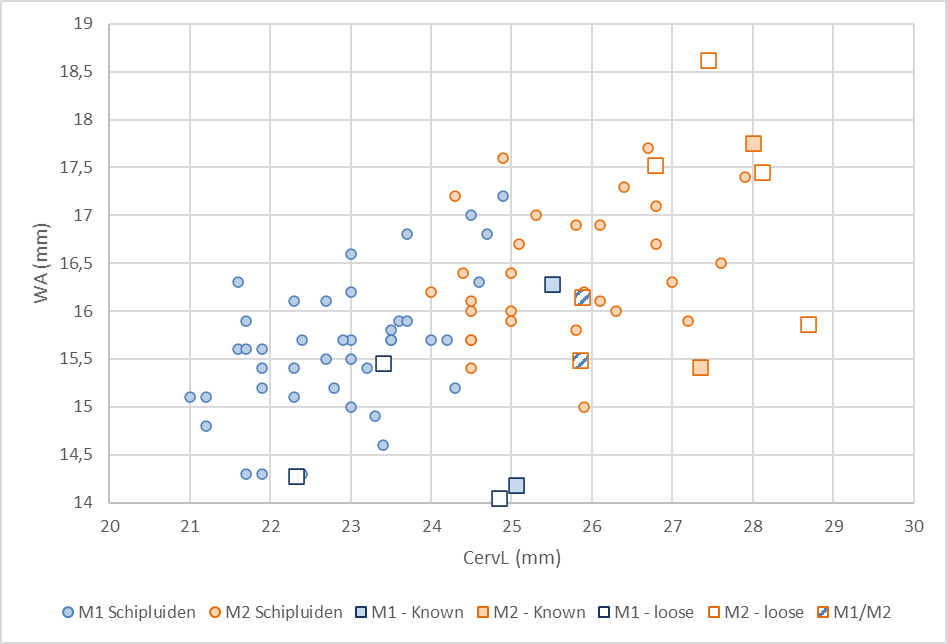


Figure S7. Boxplot of Logarithmic Size Index (LSI) analysis of Sus postcranial elements compared to Polderweg and De Bruin (Brusgaard et al. 2022), Schipluiden (Manning et al. 2015) and Durrington Walls (Albarella & Payne 2005).

Figure S8. Identification of loose mandibular M1/M2s based on the length of cervical (CervL) and width of the anterior (WA) compared to four known M1 and M2 specimens from S3 and to Schipluiden reference data from Kamjan et al. (2020). Two specimens could not be identified due to their ambiguous size.

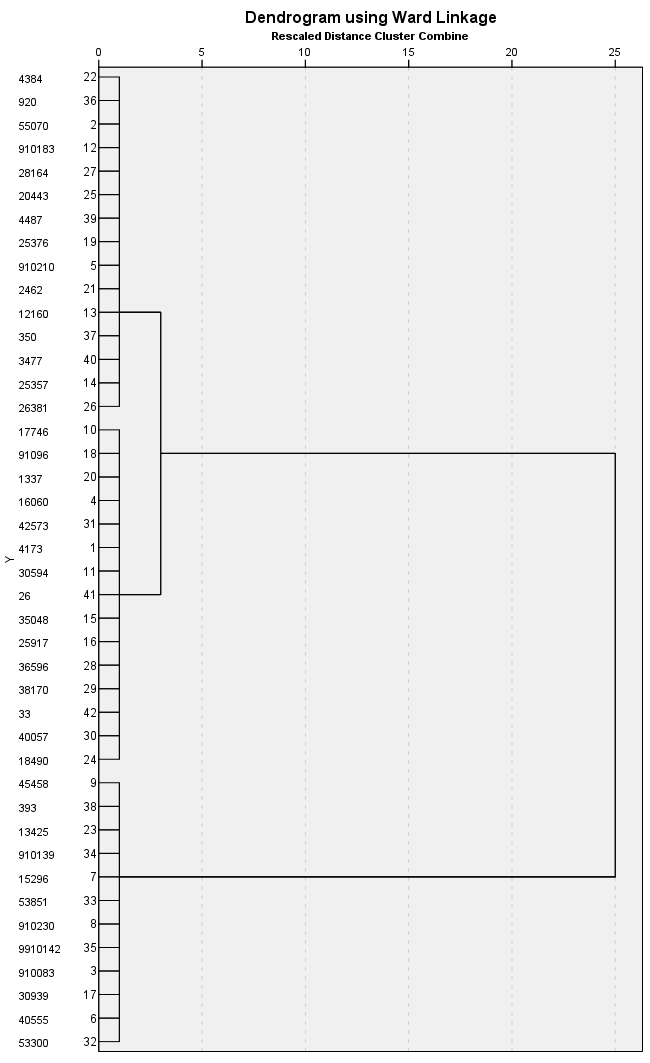


Figure S9. Hierarchical agglomerative cluster analysis using Ward’s linkage of Bos stable isotope results from Swifterbant S3, S4, and Windplan Blauw, presenting two well-defined clusters. Specimens are labelled by their Faunal ID.

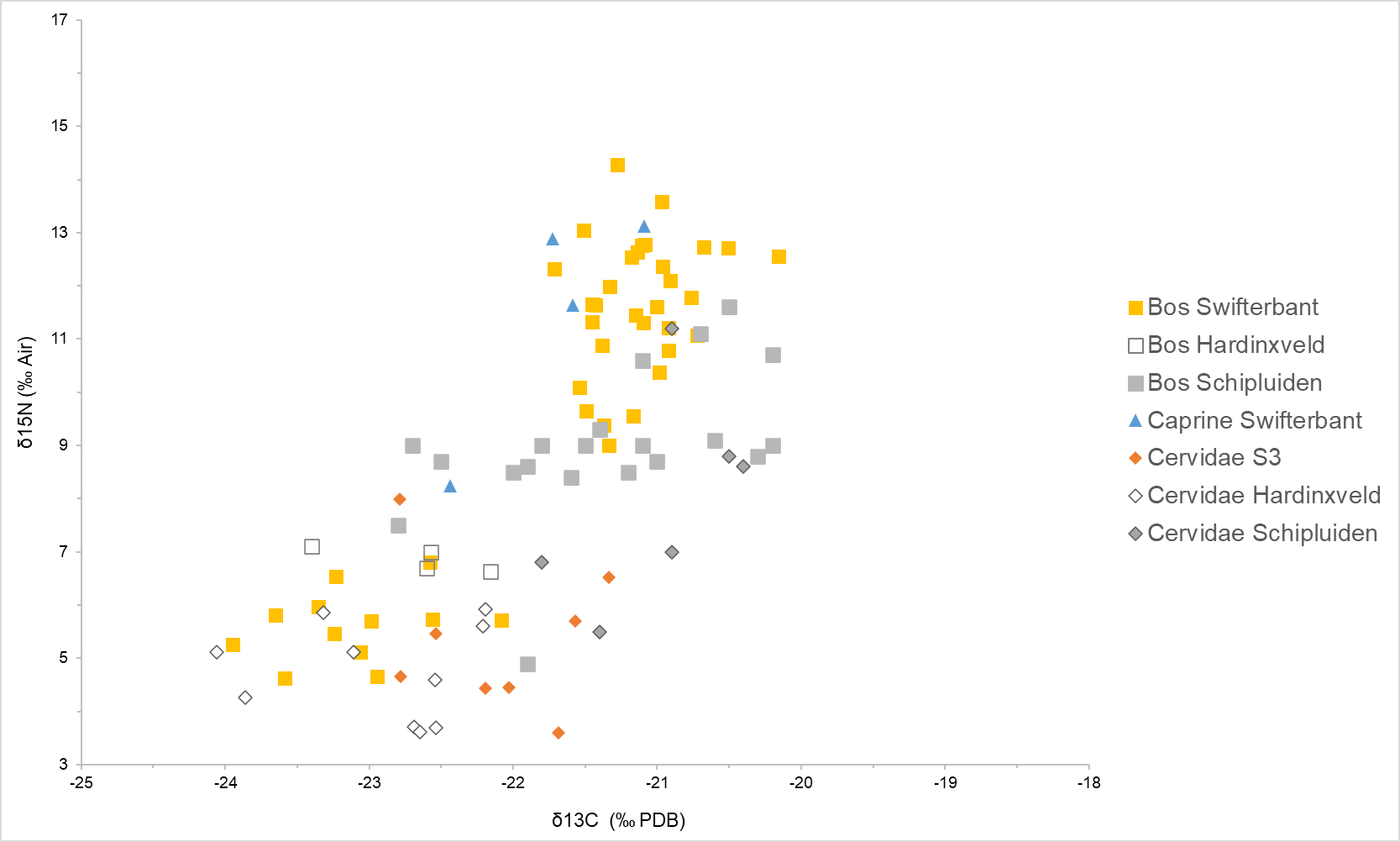
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Figure S10. The Bos and caprine δ13C and δ15N values at Swifterbant as compared to Bos and cervidae from other Dutch Neolithic sites (data for other sites from Smits et al. 2010; Çakırlar et al. 2020; Kamjan et al. 2020; Brusgaard et al. 2022).

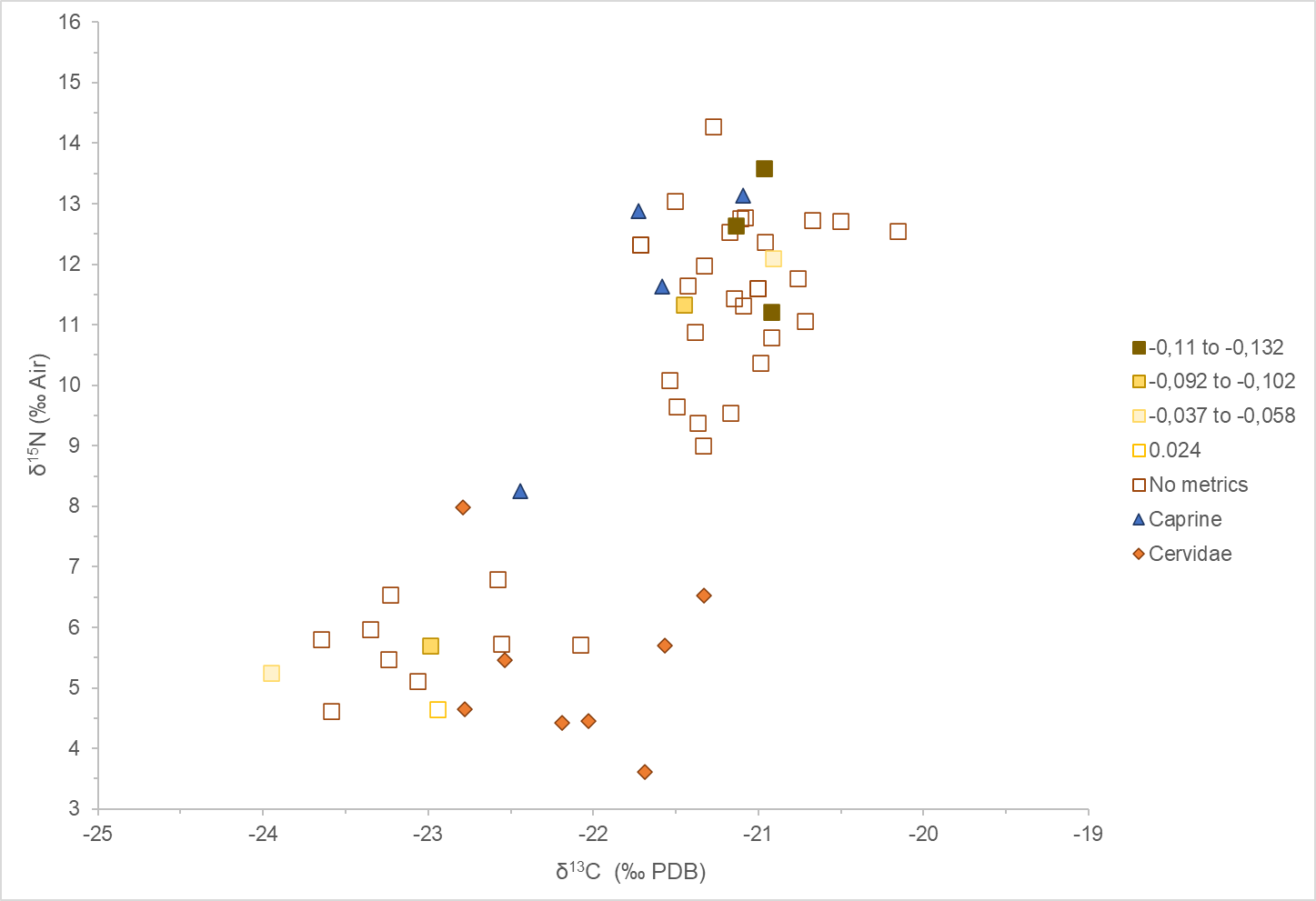


Figure S11. δ13C and δ15N values of Bos compared to their LSI values. LSI categories: -0.265 (n = 1); -0.11 to -0.132 (n = 3); -0.092 to -0.102 (n = 2); -0.037 to -0.058 (n = 2); 0.024 (n = 1); no metrics (n = 10).

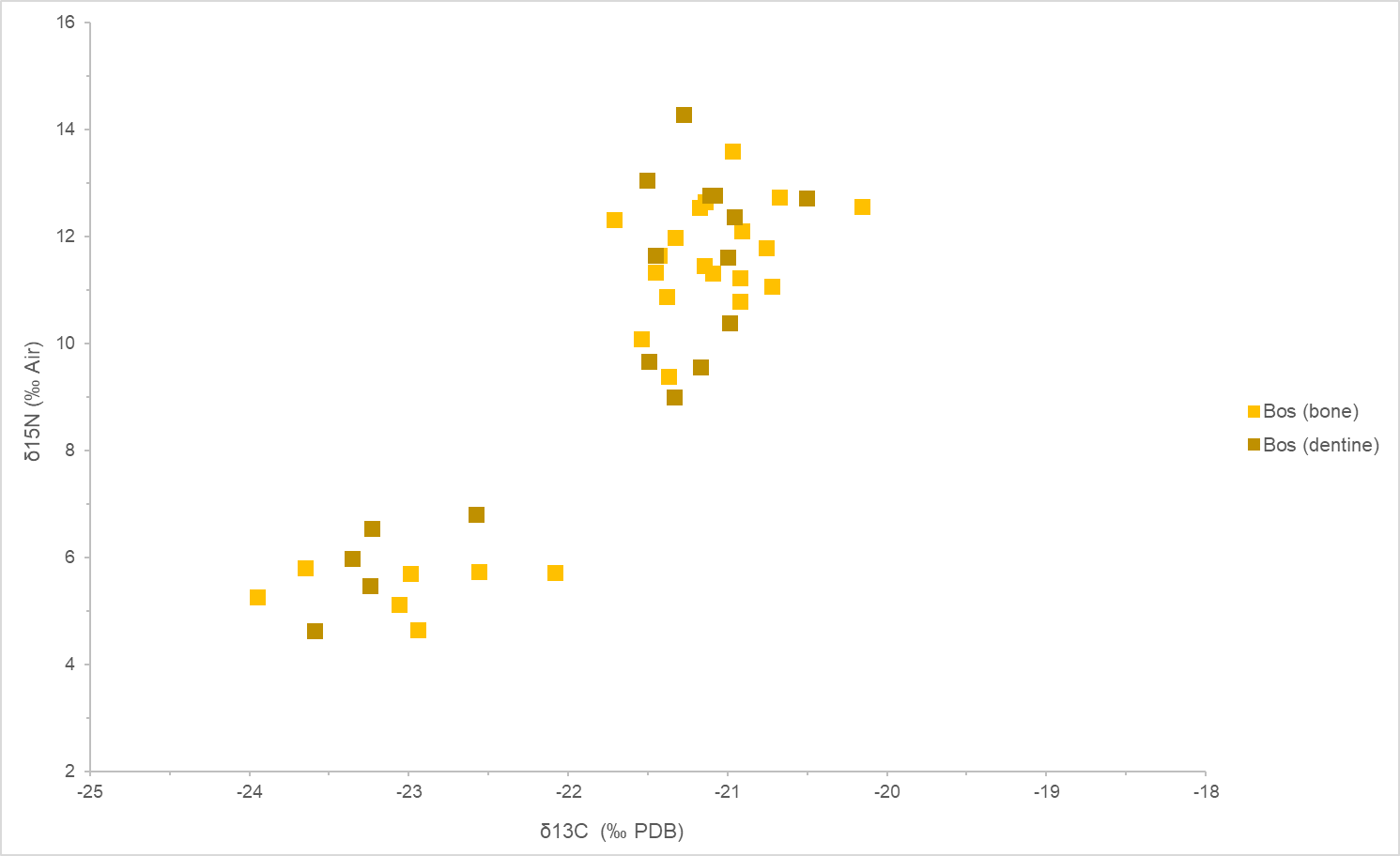


Figure S12. δ13C and δ15N results of Swifterbant Bos comparing bone collagen values and dentine collagen values.

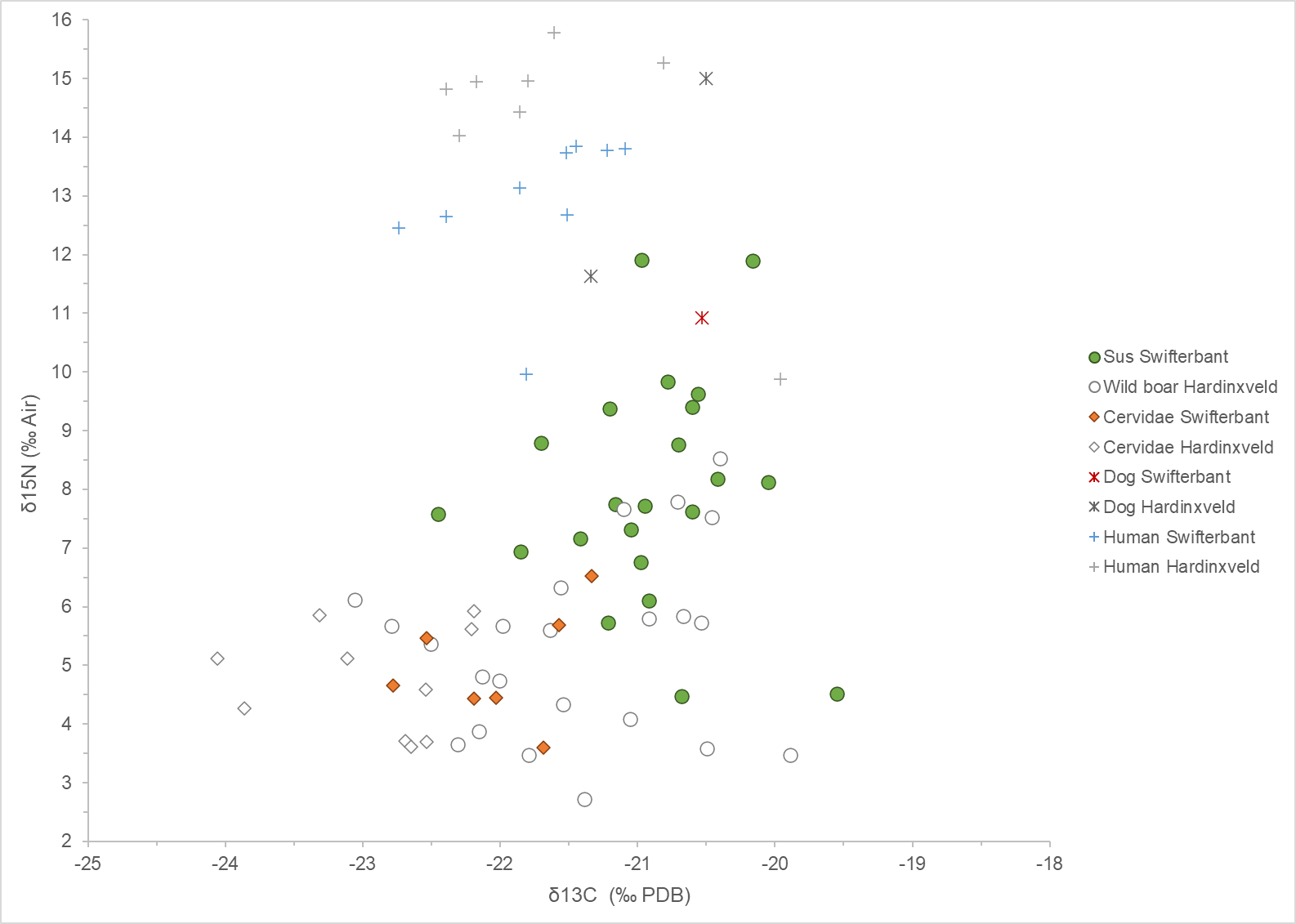


Figure S13. Suid δ13C and δ15N values at S3 compared to the wild boar from Hardinxveld Polderweg and De Bruin (data from Brusgaard et al. 2022).

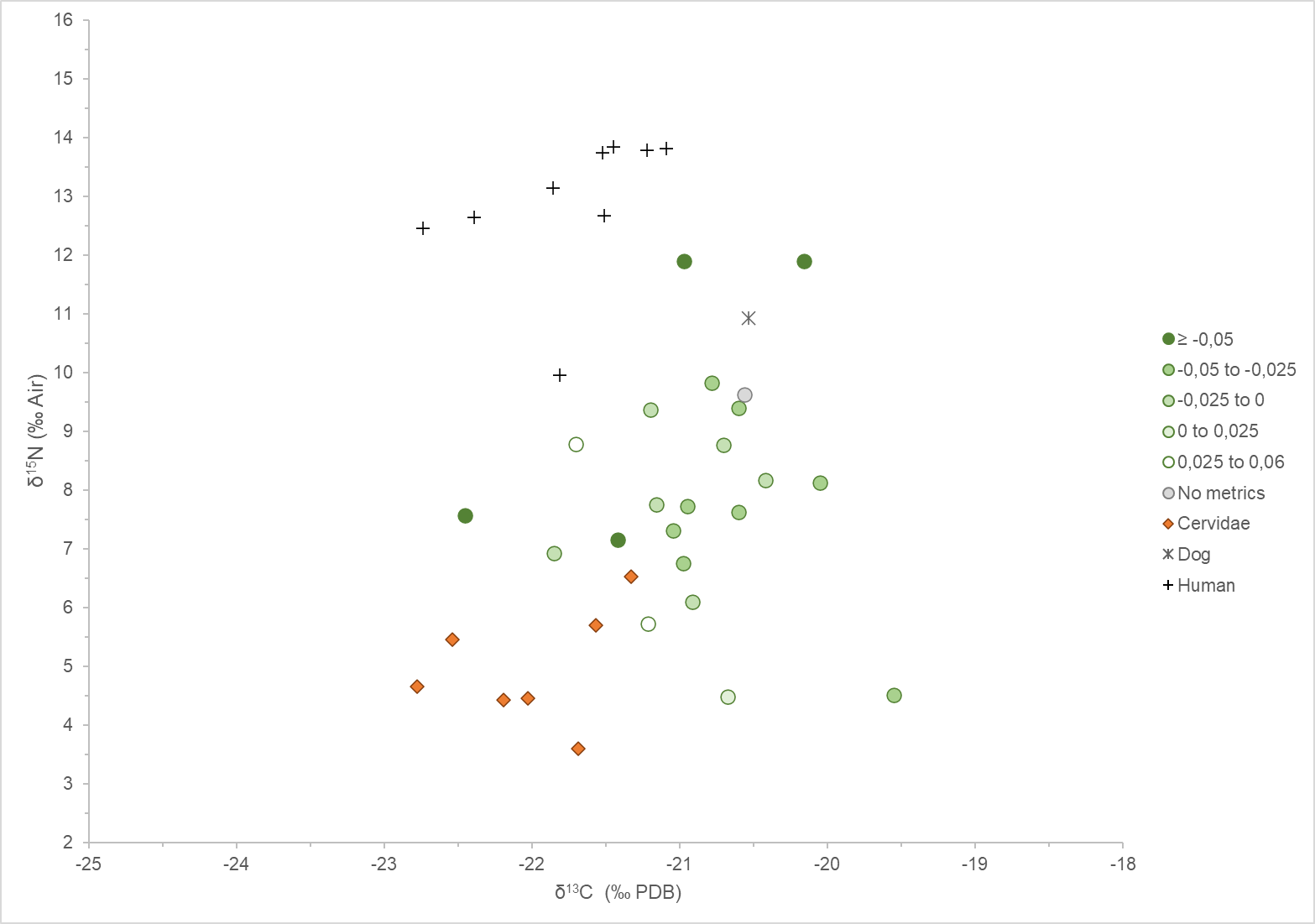


Figure S14. δ13C and δ15N values of suids compared to their LSI values. LSI categories: ≥ -0.05 (n = 4); -0.05 to -0.025 (n = 8); -0.025 to 0 (n = 6); 0 to 0.025 (n = 1); 0.025 to 0.06 (n = 2); no metrics (n = 1). Note that this includes skeletal elements measured on two different LSI scales (postcranial and dental).



Figure S15. Map of the Swifterbant sites S2, S3 and S4 and the Windplan Blauw samples, along the contemporary freshwater river system.

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