eTopoi Journal for Ancient Studies

Special Volume 6 (2016): Space and Knowledge. Topoi Research Group Articles, ed. by Gerd Graßhoff and Michael Meyer, pp. 102–151.

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The Textile Revolution. Research into the Origin and Spread of Wool Production between the Near East and Central Europe

Edited by Gerd Graßhoff and Michael Meyer, Excellence Cluster Topoi, Berlin

eTopoi ISSN 2192-2608
http://journal.topoi.org

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The Textile Revolution. Research into the Origin and Spread of Wool Production between the Near East and Central Europe

The objective of the research group *Textile Revolution* is to contribute to research on the still largely unclear introduction of wool production in later Neolithic and Chalcolithic societies from Western Asia to Central Europe. Since direct evidence of wool depends on rare conditions of preservation, a multi-proxy approach based on different kinds of indirect evidence was chosen. The previous history of research on early wool production as well as the domestication history of sheep are reviewed briefly. Anthropogenic impacts on the landscape, possibly related to intensified grazing, are one kind of indirect evidence that we take into account. For the later part of the presumably long-lasting development of wool production, written sources are available, the earliest of which date to the Late Uruk and Jemdet Nasr periods (end of the 4th to beginning of the 3rd millennium BCE) in Mesopotamia. Indirect archaeological evidence consists of the tools used in textile production, among which spindle whorls and loom weights occur most frequently. Since they are not *a priori* specific to the type of fibre, be it linen or wool, statistical evaluations of metric data are necessary. Zooarchaeological analysis of large samples of animal bones from a wide spectrum of sites and time slices is a further crucial element of our multi-proxy approach. Both the demographic composition of herds and metric data indicating changes in animal size can yield indirect evidence for incipient or increasing importance of wool production. This article offers an overview of these different sources and methods, specific to the disciplines involved, and presents some preliminary results.

Textiles; wool; textile tools; archaeozoology.

1 Introduction

Wool production is closely connected to the domesticated sheep and specifically to those animals that carry a woolly coat. With the keeping of woolly sheep, not only did the economy of a large number of prehistoric communities over a vast region change, but also the textile technology, the equipment for the production of garments and not least people's appearance. Even the identity of persons and their social status were expressed through new kinds of textile products. The origin of woolly sheep and the paths and speed of their dispersal throughout the Old World are still open questions and form one of the major topics in this research project.

Beyond the question of biological origins, it is crucial to consider the social and technological innovations that accompanied, or perhaps spurred, the development and exploitation of wool. The substitution of the archaic hairy form by the woolly sheep, although triggered by a series of genetic mutations, turned into one of the major innovations in prehistory, providing people with the raw material for a greater variety of textile products that could be harvested yearly. As compared with flax wool has a number of advantages: it offers better thermal insulation properties than linen and is water-repellent.

Woollen threads can be spun in various thicknesses and qualities, and woven or knitted textiles made of wool are usually softer and can be dyed in a greater variety and intensity of colours.[1] The process of wool harvesting and preparation is less time consuming than flax production.[2]

Once milk and especially wool had become predominant products of sheep husbandry, not only the economic importance but also the size of sheep flocks can be expected to have grown considerably. Large herds can be relatively easily managed by a single person with the help of one or two dogs. Since the nutritional demands of sheep are quite different from other livestock such as cattle, sheep husbandry may have developed as a form of subsistence that was complementary to agriculture. Flax cultivation requires high quality agricultural land and thereby competes with food crops; it also has a relatively high water requirement. In contrast, sheep can be grazed on marginal land that is unsuitable for cultivation. Moreover, large flocks had to be removed from the vicinity of fields in order to ensure that crops would not be decimated by grazing animals.

Sheep adapt well to dry and moderately mountainous environments as well as humid and windy grassland areas. A prerequisite of sheep husbandry is an open landscape with sparse tree cover, as is widely available throughout western Asia. Regular grazing of sheep effectively prevents or slows down natural forest recovery, as several studies have shown.[3] In those parts of Europe in which forest cover is not restricted by climatic factors (arid and sub-arctic zones, wind exposed coastal fringes of western Europe), sheep husbandry can be expected to gain importance in the course of increased anthropogenic opening of the primeval forest vegetation. This is one hypothesis to explain the relatively late occurrence of a large-scale and widespread specialised sheep husbandry in most parts of Europe in contrast to western Asia. Hence, to follow the track of sheep in Europe necessarily includes research on ancient landscapes, another pivotal part of this project.

For ancient Mesopotamia McCorriston has proposed a fundamental shift from linen-based to woollen textile production.[4] Drawing on evidence from cuneiform texts as well as faunal and botanical remains, she suggests that it was in the 3rd or perhaps late 4th millennium BCE that wool became the fibre of choice for everyday use. Recent archaeological and archaeozoological research, however, suggests a considerably earlier date, before the advent of writing. Written sources from the mid- to late 3rd millennium BCE demonstrate that sheep and goats were maintained in herds of some dozens to a few hundred and herded in large flocks up to several thousand animals. In fact, cuneiform records provide ample evidence for the usage of wool in textile manufacture, whereas linen appears only rarely. The growth of a large-scale woollen textile industry rested on women as the main source of labour.

Over millennia sheep (and goats) were exploited for a variety of reasons: people used their wool (hair) and dairy products, but also meat, hooves, horn, sinews, skins, bones etc.[5] Only in certain cases such as in Assyria, Babylonia and the Minoan and Mycenaean realms was sheep husbandry exclusively focused on wool production. Since wool was the primary commercial good which was exported in exchange for strategic resources unavailable in Mesopotamia proper, as metal, wood, stone, spices, and the like, sheep husbandry and the textile industry became the most important sub-branch of Mesopotamian political economies.[6] The pre-eminent role of the woolly sheep is highlighted in an early 2nd

1 Barber 1991.
2 McCorriston 1997, 522–523.
3 Belsky and Blumenthal 1997; Putfarken et al. 2008; Hannon and Bradshaw 2000.
4 McCorriston 1997.
5 Waetzoldt 1972, 4; Hruška 1996, 83–92; Englund 1998, 143; Postgate 2009.
6 Englund 1998, 251–254; Pomponio 2010, 187.

millennium BC Sumerian debate poem in which the ewe features as the counterpart of the grain, which provided the economic basis for urban culture.[7]

1.1 Wool and the 'Secondary Products Revolution'

The domestication process as well as the development of the sheep fleece has been the subject of different scientific studies including but not limited to archaeological ones,[8] but it is usually put into the context of use of other secondary products from domestic animals, such as milk, traction, and manure.[9] The distinction between primary products, which can be obtained from animals only once by killing them, and secondary products that are supplied by the animal regularly or occasionally during its lifetime, was used in earlier archaeozoological literature.[10] Andrew Sherratt, however, was the first to assemble various types of evidence from archaeology and archaeozoology into a consistent model, which he called the Secondary Products Revolution (SPR). He first published these ideas in 1981 as homage to the late David Clarke[11] and was obviously inspired by processual approaches of the 1970s.[12] He suggested that the main secondary products of Old World domesticated animals, traction (plough and cart), riding (donkey, horse), milk and wool, occurred first in a fairly narrow time span in the 4th millennium BC, thus being later economic achievements of animal husbandry that developed several millennia after primary domestication in the Near East. Primary animal products, mainly meat, would thus be considered the only objective of Neolithic herders, whereas Sherratt regarded the full range of animal exploitation as an achievement of the Chalcolithic. What made Sherratt's article so groundbreaking and influential was not only his masterly synthesis of different strands of evidence, but also his assessment of the potential of secondary animal products for cultural evolution and social complexity at the transition of the 4th to the 3rd millennium BC.

Sherratt's model received approval, but also some critique soon after its first publication. While John Chapman doubted the late introduction of the plough,[13] Peter Bogucki suggested a much earlier use of milk, based on clay sieves from Kujavian LBK and Stroke Pottery sites.[14] While even today evidence for the plough in Europe before the mid-4th millennium is lacking, milk lipids have been found in a wide range of pottery, extending from coastal sites at the Marmara Sea in the early 6th millenium to early Neolithic Britain.[15] Most recently lipid residues of milk from ruminants (cattle, sheep, goat) have been identified in a number of early Neolithic sieves from Kujavia, confirming Bogucki's interpretation published more than 30 years ago.[16]

A substantial critical revision of Sherrratt's SPR by Markus Vosteen appeared in 1996.[17] Vosteen disputed a (roughly) contemporaneous occurrence and/or intensification of secondary animal products. Claiming that evidence for the earliest use of milk, traction, riding and wool is spread over a long period from the later 6th to the early 3rd millennium cal BC, he suggested regionally independent and chronologically diverse adoptions of

7 Alster and Vanstiphout 1987; Postgate 2009, 119.
8 Gleba 2011.
9 Helmer, Gourichon, and Vila 2007; Sherratt 1981; Sherratt 1983.
10 Bökönyi 1974.
11 Sherratt 1981.
12 Sherratt 1981, 285–290 and fig. 10.16.
13 Chapman 1982.
14 Bogucki 1984; Bogucki 1986.
15 Evershed et al. 2008.
16 Paper presented by Penny Bickle, Melanie Roffet-Salque and Richard Evershed (Bristol University) at the Prehistoric Society Europa Conference, Cardiff, May 2014.
17 Vosteen 1996.

existing technologies. Vosteen implicitly discards the concept of innovation as a dynamic process that depends on communication, transfer of knowledge and social as well as economic assessments by the communities involved. Being published in German, his paper failed to receive much attention in the international scientific community, despite a comprehensive reply by A. Sherratt himself, discussing and disproving most of Vosteen's critical arguments.[18]

Within archaeozoology, one of the most committed supporters of Sherratt's SPR has been Haskel Greenfield.[19] Recently he argued for a revision of the absolute contemporaneity of its components and emphasized that the SPR consists rather in an intensification in scale of secondary product use. According to Greenfield, even if the use of milk has to be shifted backwards in time by more than two millennia, the basic concepts of Sherratt's model are still valid: only after the Neolithic, during the (later) Copper age do we find the first evidence for traction, plough and cart as well as for sheep wool.

The economic relevance of secondary products, even if they are known for a long time as is the case for milk, increases considerably during the fourth millennium, while the origin and paths of dispersion appear far less clear than at the time of Sherratt's 1981 publication. The quantity and chronological resolution of the evidence for secondary animal products have considerably improved over the last two decades. For the earliest wheeled transport requiring animal traction, dates cluster between 3400 and 2700 cal BC.[20] Claims for riding before the 4th millenium cal BC have been convincingly questioned by Benecke.[21] For the first substantial use of sheep wool and the introduction of specialised sheep husbandry to prehistoric Europe, however, neither has the evidence grown considerably nor has its time resolution improved since Sherratt's first publications.

1.2 Previous archaeological research on textile production

The importance of textiles does not correspond to the rate of publication about them, which rather reflects the elusiveness of the material proper. The preservation of textiles in archaeological contexts is dependent on soil conditions and microbial activity. The pH-value of soil affects conservation of animal and vegetal fibres differently: vegetal fibres decay in acidic conditions, whereas protein-based animal fibres favour neutral (pH=7) soil conditions and dissolve in an alkaline milieu.[22] The appearance of both types of fibres in the same context is rare and occurs in cases of reduced microbial activity due to desiccation (e.g. Shahr-i Sokhta[23], Nahal Mishmar[24]), low temperatures (e.g. Ötzi[25]) or high amounts of salt (e.g. Hallstatt[26], Douzlakh Chehrabad[27]).

The earliest textiles found in archaeological contexts are made from vegetal fibres (mainly flax), e.g., the fabrics from Neolithic Catal Höyük[28], Halula[29] and Nahal Hemar[30].

18 Sherratt 1996.
19 Greenfield 1986; Greenfield 1988.
20 Fansa and Burmeister 2004.
21 Benecke 2002.
22 Grömer 2010; Cybulska and Maik 2007.
23 Good 1999; Costantini, Esfahani, and Sajjadi 2009.
24 Bar-Adon 1980.
25 Winiger 1995.
26 Bichler 2005.
27 Hadian, Good, and Pollard 2012.
28 Burnham 1964; Burnham 1965; Helbaek 1963; Ryder 1965.
29 Molist Montana 2001, 43.
30 Schick 1988.

Despite their early date they already show a wide range of diverse textile techniques.[31] Wool of a certain staple length could have been integrated easily into this setting in which spinning of fibres to produce filaments and weaving and twining to produce fabrics were already well known.

Even though wool was certainly used for non-textile purposes such as bedding, pillows, temper or stuffing material in construction, its major advantage lies in its suitability for the production of textiles. This advantage is closely related to the length of the wool staples, as very short staples will inhibit the creation of a strong yarn.[32] The development of longer wool staples is therefore crucial for wool use in textile production.[33]

The first intensive examination of prehistoric textiles occurred in regions where they were preserved in archaeological contexts, e.g. the Neolithic lake dwellings in southern Germany and Switzerland,[34] the Danish bog finds[35], and in the Near East in Dura Europos[36], the Judean Desert[37] and Çatal Höyük[38]. Due to the limited amount of material evidence, much research in the Near East concentrated on textual sources.[39] Apart from pioneering studies of textile traditions in Romania[40] and Bulgaria[41], which only took into consideration archaeological evidence from confined geographical sections and the final results of which remain unpublished, diagnostic objects from a large area of southeastern and central Europe have not yet been systematically studied. Elizabeth Barber's book *Prehistoric Textiles*[42] marks a change in the perception of textiles in archaeology. It was the first comprehensive compilation of research on textiles, offering insights into technology, tools, and iconographic evidence on a very broad geographical scale, including Central Europe, Egypt and the Near East.

In the Near East some recent studies have concentrated on exploring textile technology in general, including evidence from actual textiles, their impressions, iconographic evidence and textile tools.[43] Their approach is aimed at better understanding of technological details of the *chaîne opératoire* in textile production and narrating the development of these techniques through time and space. Other studies are based on a set of textile tools and textile remains from a single site (e.g. Ebla[44], Arslantepe[45], Hacinebi[46]) focussing on details of their production within these sites. Within the category of textile tools, spindle whorls are treated with special attention, as they can potentially be analysed to address questions of gender and ethnicity[47], textile production[48] and as a proxy for the determination of fibre material[49].

The common absence of actual textiles and fibres has led to growing reliance on proxy indicators. Textile tools have become a main focus of current research aiming at explaining technological development that potentially meets new demands connected to greater

31 Breniquet 2008, Table III.
32 Barber 1991.
33 Ryder 1964; Ryder 1969; Ryder 1993; Gleba 2011.
34 Heer 1872; Vogt 1937.
35 Broholm and Hald 1935; Brønsted 1950.
36 Pfister and Bellinger 1945.
37 Schick 1989.
38 Burnham 1964; Burnham 1965; Helbaek 1963; Ryder 1965.
39 Bibliography cf. Section 1b.
40 Mazăre 2012.
41 Petrova 2011.
42 Barber 1991.
43 Völling 2008; Breniquet 2008.
44 Peyronel 2004; Andersson et al. 2010.
45 Laurito et al. 2009.
46 Keith 1998.
47 Keith 1998.
48 Kimbrough 2006.
49 Sudo 2010; Rooijakkers 2012; Keith 1998.

specialization, intensified production and/or introduction of new raw materials. Recent studies often rely on experiments to elucidate the original use and function of textile tools in connection to different fibers. Although the geographical and chronological framework of these studies does not cover the full scope of our research, their approach and results are taken into account in addressing questions of fiber distinction in our work.[50]

1.3 Domestication history of the sheep

Today, more than 1 000 different breeds of sheep are known, kept for mutton, milk or wool (Fig. 1), and sheep husbandry still has a deeply entrenched place in the cultures of many people. The sheep was one of the earliest ungulate species to be domesticated for agricultural purposes. It is an accepted view among specialists that the domestication took place in the Fertile Crescent, most probably in multiple areas, during the 9th millenium BC (Tab. 2)[51]. The ancestor of the domestic sheep was most likely the Iranian subspecies of the Asian wild sheep, *Ovis orientalis* (Fig. 1a)[52]. The domestication process lasted over an extended period of unknown duration with different stages of adaptation, taming and breeding of animals, until they were entirely adapted to the human-made environment. Only then did populations of domestic sheep exist that were large enough to guarantee a successful life-stock keeping over time. In the course of this process, genetic changes occurred, and the phenotype of the animals changed considerably. That included a reduction of body size, a diversification of shape and size of skulls and horns, a shift in the proportions of the body and changes in colour and quality of the coat. Some of these changes are reflected in the morphology of the skeleton, others not.

The coat of the early domestic sheep resembled that of its wild ancestor and still can be found in mouflons from Sardinia and Corsica (Fig. 1b). This old domestic breed survived in a feral state. European mouflons grew thick, coarse-grain hair or kemp with an undercoat of fine, curled underwool growing annually in autumn and shed in spring. This hair – be it from wild sheep or from an early domestic form – could be caught on branches or plucked by hand (called rooing) when it fell off the animals' bodies in heavy clumps. It is not known if the original hairy coat was already used in prehistoric periods (which also brings into discussion the exploitation of hair from wild animals such as deer, foxes or wild equids, something that might have preceded the exploitation of wool). What we do know is that the first domestic sheep were kept primarily for their meat, although recent studies of lipid residues in pottery suggest the use of sheep milk earlier than previously expected – maybe even from the early stages of domestication.[53]

The agents and events that led to the development of the woolly sheep are still only rudimentarily understood. What seems clear is that the woolly sheep was not 'invented' by people. More probably, a series of genetic mutations occurred, induced by or as a side effect of human sheep breeding, maybe encouraged in some areas under the influence of different ecological conditions. The mutations resulted in different coat qualities:[54]

50 The Danish National Research Foundation's Centre for Textile Research (CTR): Tools and Textiles – Texts and Contexts (TTTC) Research Program.
51 Fuller, Willcox, and Allaby 2011.
52 Ludwig and Benecke 2003.
53 Craig et al. 2005.
54 Ryder 1968; Ryder 1969.

a

b

Fig. 1 | a. Wild sheep (*Ovis orientalis*); b. Mouflon in the Berlin Zoo.

- the hair and kemp fibres became reduced
- the fine underwool of the winter undercoat became longer and more abundant
- the undercoat did not change seasonally any more but grew continuously
- the hair lost its pigmentation

Once the usefulness of wool was recognised, stockbreeders might have fostered and accelerated the development by selective breeding. Sheep with hairy coats were gradually replaced by those carrying wool. We have to consider that through successive and selective breeding over a longer time period, the wide variability in the nature of the fleece became apparent. The selection of sheep with easily dyeable white fleece might have begun quite early and spread quickly over large regions. A strategic economic shift was also accomplished, keeping more sheep to an older age in order to increase the amount of wool available. Even the castration of males was practised, because castrated animals deliver wool in better quality and higher volumes than rams. With the use of wool fibres, new technologies and equipment were brought into existence. In a region as yet unknown – but presumably in Mesopotamia – these events are thought to have occurred in the 6th to 5th millenium BC.[55] Later on, keeping of woolly sheep was routinely and systematically practised on a larger scale.

Most interestingly, these stages of development are reflected as well in the European history of the domestic sheep. As far as we know, the Neolithic package spread over Europe over more than two millennia in distinct, successive stages rather than in a continuous dispersion process.[56] One of the first waves brought domestic sheep with hairy coats to Europe (still visible in the feral mouflons on Sardinia and Corsica), followed by later waves in which woolly sheep were included. In the beginning, these sheep may have carried relatively short woolly fleece, as can be seen in the Soay sheep, while later on sheep with much finer and longer wool were involved. In Thessaly and/or in Thrace, sheep with woolly fleece are supposed to have appeared for the first time on European ground at the end of the 4th millenium BC.[57] A growing wool production was established during the Bronze Age.[58]

Already at the time of Sherratt's "secondary products revolution" hypothesis,[59] indications for changes in sheep husbandry existed, as demonstrated by the work of many archaeozoologists. However, in most of the publications only limited data on herd structure or sheep management strategies were presented. In particular the question of the emergence of secondary products has provoked much discussion.[60]

In the meantime, the number of sites with relevant faunal remains has grown, and it is now worthwhile carrying out a large-scale evaluation of the corpus of published data.

1.4 Potential impact of animal grazing on prehistoric landscape development

Landscape alteration is a multi-factorial process and the result of complex interaction between different subsystems including atmosphere, geosphere, biosphere and hydrosphere. Human activity interferes with each of the subsystems. Dynamics of landscapes, i.e. the sensitivity to react to a particular impact, are highly diverse and depend on the vulnerability and resilience of the different components. In order to limit the complexity and to allow a certain degree of comparability, we focus here on the European mid-latitudes, which themselves encompass considerable heterogeneity.

In central Europe, postglacial landscape development is characterized by climate trajectories towards moderate temperature and precipitation conditions. This favoured succession processes that led to increasing vegetation cover and the development of closed primary woodlands consisting of mixed deciduous forests in the lower and mid-altitudes and mixed coniferous forests in the higher and colder regions.[61] Characteristic soils developed according to the parent bedrock, relief and meso-climatic conditions. Bork emphasises overall poor morphodynamics for central Europe and erosion processes reduced to a minimum.[62]

55 Benecke 1994, 137.
56 Schier 2009.
57 Benecke 1994, 137–138.
58 Halstead 1981.
59 Sherratt 1983.
60 Cf. Curci and Tagliacozzo 1998; Curci and Tagliacozzo 2003; Vigne and Helmer 2007; Greenfield and Fowler 2003; Greenfield 2005.
61 Ellenberg 1996.
62 H.-R. Bork, H. Bork, and Dalchow 1998.

These phases of a stable landscape with an equilibrium of soil formation, soil loss and vegetation succession was disturbed by increasing human activity from the Neolithic onwards; systematic grazing of domesticated animals was one of the important factors in land degradation (Fig. 2).[63]

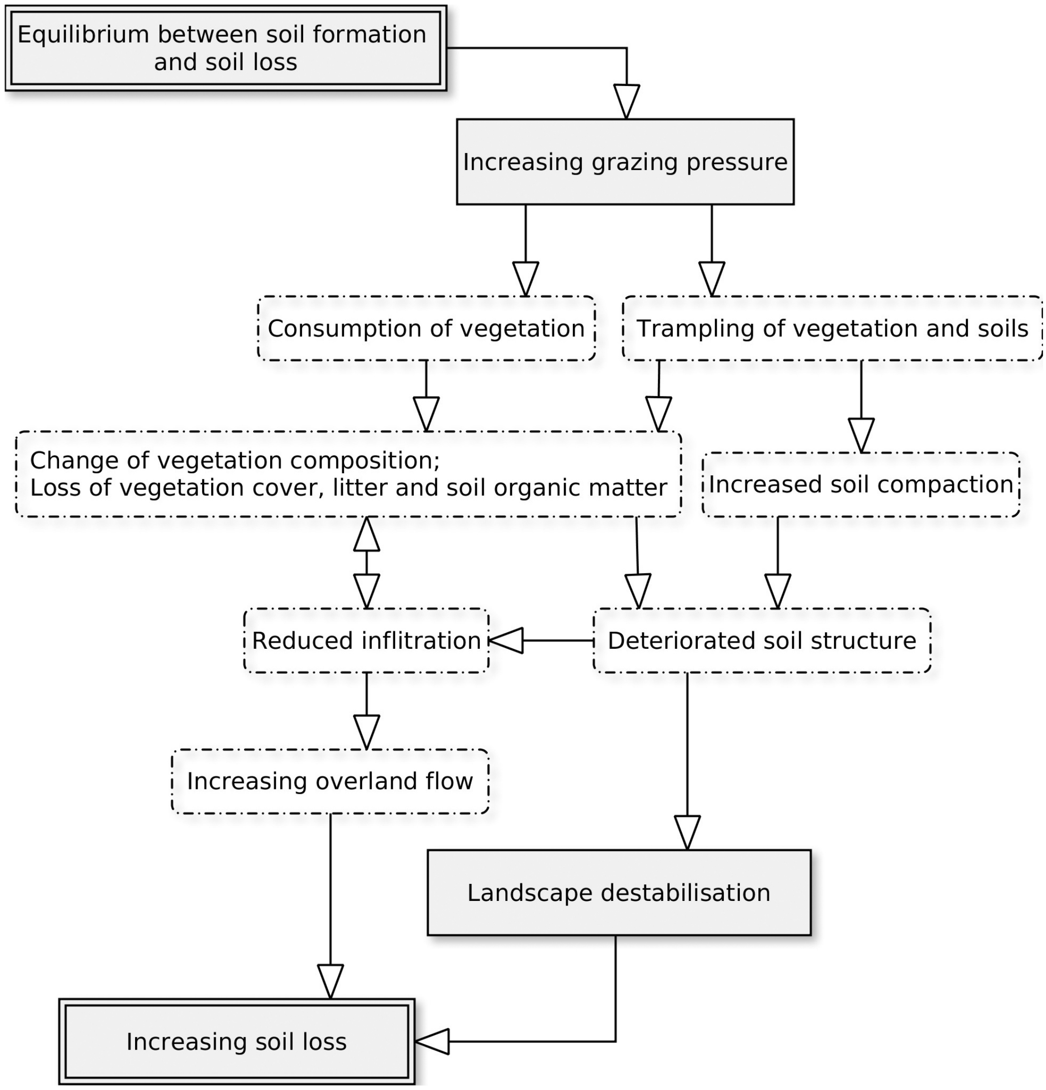

Fig. 2 | Process structure of land degradation due to grazing.

However, specific cause-effect hierarchies are hardly provable for prehistoric landscape development, as pointed out by Belsky.[64] In northwestern Germany the first anthropogenic disturbances are linked to the Landnam phase when people of the younger Funnel Beaker Culture started to use forests as pastures year-round, and settlement indicator species such as *Plantago lanceolata* and weeds increased, whereas tree cover decreased and open *Hudewälder* developed around settlement areas. Where grazing pressure lasted for longer

63 Behre 2002.
64 Belsky and Blumenthal 1997.

periods and vegetation was less resilient due to poor soils, heath landscapes developed locally as the next degradation state.[65]

In the Rhineland the transition from closed forests to permanently open vegetation due to human impact is attributed to the Iron Age, although causes of this process are not further specified.[66] Studies around Lake Constance find ephemeral use of woodlands already represented in pollen records for the early Neolithic, whereas the conversion towards a cultural landscape with arable farming and pasture is ascribed to the Early Bronze Age.[67]

Around the Mediterranean vegetation changes before 4000 cal. BP were mainly due to climatic variations, and only from then onwards did human-induced land cover changes become more and more important as driving factors for environmental development.[68] Reviewing several case studies, Butzer attributes a first phase of agropastoralism and open woodlands in the southern Argolid to the Early Bronze Age when modest land use intensity is characterized by upland grazing and partial clearance not being particularly destructive to the landscape.[69] With the beginning of the Late Bronze Age, pollen assemblages indicate partial opening of the vegetation cover and establishment of maquis. Butzer links this development to archaeological evidence implying sheep and cattle as predominant domesticates, whereas wild animals represent only 5% of the bone assemblages. This phase is seen as the first period of intensified pasture and agricultural land use. Dusar synthesizes 53 case studies to reconstruct Holocene environmental change in the Eastern Mediterranean.[70] He finds the first anthropogenic indicator pollen around 6500 years cal. BP in Anatolia, whereas human impact on the landscape became much more visible in the Late Bronze Age with the beginning of the Beyşehir Occupation Period between 3500–1500 years cal. BP. Dusar concludes that during this period forest burning and clearance, intensive agricultural practices and grazing were the main processes causing vegetation change, while climate change still acted as a trigger for erosion.

Differentiation between environmental change due to human and climate impact, respectively, is possible for areas of sub-continental scale.[71] However, further differentiation between the effects of different kinds of human impact needs much more careful consideration of specific site conditions and the integration of abundant archaeological findings as well as environmental data. Therefore, effects of particular human activities during prehistory are reported only for small-scale case studies in connection to deduced socio-economic models. Mostly causal links between human activities and processes such as erosion and aggradation are obscured by the multiple interdependencies between different environmental processes and human influences.

Nevertheless, where data are of high quality, causes for vegetation degradation can be determined. Using tephra chronology and pollen evidence Hallsdottir states that in southern Iceland birch woodland around settlements vanished between 1030 and 1079 cal. BP.[72] Regeneration was inhibited due to intensive sheep grazing, and heathland and mires expanded at the expense of former woodland. Similar processes occurred on the Faroe Islands.[73]

Recent impacts of sheep grazing are reported for Kyrgyzstan where herding pressure exceeded landscape carrying capacity by a factor of two to three during Soviet times. This

65 Behre 2002.
66 Lechterbeck, Kalis, and Meurers-Balke 2009.
67 Kerig and Lechterbeck 2004.
68 Jalut et al. 2008; Roberts et al. 2011; Sadori, Jahns, and Peyron 2011.
69 Butzer 2005.
70 Dusar et al. 2011.
71 E.g. Butzer 2005; Dotterweich 2008; Dreibrodt et al. 2010; Dusar et al. 2011.
72 Hallsdóttir and Caseldine 2005.
73 Hannon and Bradshaw 2000.

led to a significant decline of pasture productivity, slope failures and soil erosion.[74] Specific information about grazing behaviour of sheep and respective impact on vegetation and landscape dynamics is reported from several case studies.[75]

1.5 Previous research on written sources relating to textile production in the Near East

Previous research on early sheep husbandry and textile production in the cuneiform record has provided general descriptions of lexicographical aspects of sheep and goat, administrative structures of herding and wool processing, terms for textiles and clothes, techniques involved in manufacturing textiles, and socio-economic significance of clothing. These are documented in specific archives, places or periods.

Late Uruk and Jemdet Nasr sheep husbandry and textile production have basically been discussed by Green, Szarzyńska and Englund.[76] ED IIIb Lagash husbandry is the subject of studies by Deimel, Hruška, Bauer and Wu.[77] Sallaberger discussed sheep and flocks according to tablets from Tell Beydar.[78] Waetzoldt provided a monographic treatment of Ur III sheep husbandry and textile production,[79] complemented by several case studies on the basis of texts from specific archives or places, as Garshana and Umma, which also include its administrative dimensions.[80] Adminstrative aspects of herding according to Ur III texts have been treated by Maekawa, Heimpel/Liverani.[81] Terminology for sheep and goats has been discussed, mainly based on Late Uruk and Djemdet Nasr and Ur III texts, by Heimpel, Steinkeller, Hruška, Englund and Szarzynska.[82] Waetzoldt describes techniques employed in textile production based on Ur III texts.[83] A largely archaeological overview that also takes written sources into account is found in Völling.[84] Spinning, weaving, dyeing, etc., have recently been the subject of articles by Andersson Strand, Cybulska, Firth and Nosch, mostly based on Ur III texts.[85]

Numerous studies have been devoted to the terminology for textiles and clothes, mainly based on Late Uruk and Jemdet Nasr,[86] ED III and Ebla texts,[87] as well as sources from the Sargonic[88] and Ur III periods.[89] The use of wool and hair for products such as

74 Shigaeva et al. 2007.
75 E.g. Belsky and Blumenthal 1997; Putfarken et al. 2008.
76 Green 1980; Szarzyńska 1988; Szarzyńska 1993; Szarzyńska 2002 with the critical review by Englund 2004 and generally Englund 1998.
77 Deimel 1926a; Deimel 1926b; Bauer 1998; Wu 2006.
78 Pruß and Sallaberger 2003–2004; Sallaberger 2004.
79 Waetzoldt 1972, cf. the reviews by Powell 1976 and Farber 1978.
80 Charpin and Durand 1980; Snell 1986; Stępień 1990; Stępień 1996a; Stępień 1996b; Verderame 2008; Waetzoldt 2011.
81 Maekawa 1980; Maekawa 1983; Maekawa 1984; Maekawa 1994; Heimpel and Liverani 1995.
82 Heimpel 1993; Steinkeller 1995; Hruška 1996; Englund 1998; Szarzyńska 2002; cf. also Deimel 1926a; Selz 1993; Hruška 1995; Bauer 1998 on ED IIIb terminology from Lagash. Hruška 1996 and Szarzyńska 2002 should be used with the critical reviews of Jagersma 1997 and Englund 2004.
83 Waetzoldt 1972; cf. the earlier contribution of Jacobsen 1953.
84 Völling 2008; cf. the concise descriptions in Völling 2012.
85 Waetzoldt 1972; Andersson Strand and Cybulska 2012; Firth and Nosch 2012; Firth 2013; Waetzoldt 2010; cf. the overviews in Völling 2012 and Waetzoldt 2013.
86 Szarzyńska 1988; Szarzyńska 1993; Szarzyńska 2002 with the critical review by Englund 2004.
87 Biga 1992; Pasquali 1997; Archi 1999; Rositani 2001; Pasquali 2005; Pomponio 2008; Pasquali 2009b; Pasquali 2009a; Pasquali 2010; Biga 2009; Sallaberger 2009; Biga 2010. See also the editions of respective dossiers in Biga and Milano 1984; Archi 1985; Sollberger 1986; Pomponio 2009 with the reviews of Waetzoldt 1986; Waetzoldt 1988.
88 Foster 2010.
89 Waetzoldt 1972; Pomponio 2010; Garcia-Ventura 2013.

strings, ropes, mats, and the like has been discussed by Steinkeller and Waetzoldt.[90] Dairy products have been dealt with by Deimel and Englund.[91]

Based on previous research, the present project will discuss cuneiform terminology for sheep and goats, their races and breeds. It will also deal with the quantification of sheep and goat husbandry and its role within the frame of state resource management, with regard to its local and diachronic variation and development. The correlation of cuneiform terminology for breeds and quantitative data derived from cuneiform sources with zooarchaeological evidence holds considerable promise.

2 Types of evidence for the use of wool

Since direct evidence for the production and use of wool (genetic data, preserved fibres) is lacking or restricted to rare and unrepresentative conditions of preservation, any attempt to trace early wool has to rely on indirect evidence, taking into account its inconsistencies and ambiguities. The present project takes a multi-proxy approach, making use of evidence independently collected by different disciplines. By projecting heterogenous proxies, each checked by careful source criticism, onto a common time scale (cal BC) and examining their correlations, we hope to reduce the ambiguity of each single proxy and to make their mutual temporal coincidence or divergence better visible.

2.1 Archaeological evidence

The period from the Late Neolithic to the Early Bronze Age, from the beginning of the 6th to the late 3rd millennium BC, is the time frame we have identified as appropriate for an investigation of the introduction of early woolly sheep in the Near East. During this period there is growth in social and economic complexity, leading to urbanization in the Late Chalcolithic. The corresponding timeframe in southeastern and central Europe spans the 5th to 2nd millennia BC, divided into Late Neolithic, Copper Age and Early Bronze Age, in which the introduction and spread of fleece-bearing sheep husbandry most likely occurred.

Our study of archaeological sources for early wool usage examines selected assemblages, chosen on the basis of their association with fibre processing and textile production. Material is included from relevant sites that yield a transect from eastern Iran to western Turkey, and from north of the Caucasus to southern Mesopotamia, stretching through Greece and Turkish Thrace and reaching the southeastern Alps, Tatra mountains and the east Carpathian mountains, where west Pontic and east Adriatic coasts serve as natural borders.

The artefact groups investigated for the Near Eastern scope of the project include rare finds of textiles; their absence in the European regions studied limits the research focus exclusively to indirect evidence. The scarcity of textile finds makes them inadequate as a source of information. Although woollen textiles have been identified in the 4th millennium BC[92] in the Near East, this information can only be regarded as a starting point for further investigation, marking a *terminus ante quem* for the appearance of woolly sheep.

In addition to fragments of textiles themselves, traces can be preserved by impressions in plastic materials (clay, bitumen, plaster) or the replacement of the actual fiber by anorganic substances such as corrosion products of metals or calcites (pseudomorph).

90 Steinkeller 1980; Waetzoldt 2007.
91 Deimel 1926b; Englund 1995, cf. Ryder 1993.
92 Good 1999; Shishlina, Orfinskaya, and Golikov 2003.

In either case no trace of the original organic material is preserved, but nonetheless the weave structure and spin and ply direction may be deduced depending on the quality of the imprint or pseudomorph.

In both Europe and the Near East, indirect evidence for textiles includes tools for spinning, twining and weaving, combs and brushes, but also needles and awls possibly used for fine processing and finishing, and tools for decorating or dyeing textiles. Apart from tools, buttons and other objects that are connected to clothing, objects bearing representations of people wearing textiles or production scenes, figurines of sheep, ceramic fragments with textile imprints and pseudomorphs are also included in the analysis.

During the Late Uruk and Jemdat Nasr periods in Mesopotamia, scenes appear on cylinder seals that have been interpreted as showing textile production carried out by so-called pigtailed figures.[93] A specific raw material cannot be deduced from these depictions, but the substantial number of scenes indicates a significant concern with cloth manufacture.

Spindle whorls are the most common items associated with textile production found in prehistoric contexts in the Near East and southeastern and central Europe. They are the only category of objects sufficiently well represented to hold the potential of demonstrating robust patterning. Fortunately they are at the same time the most efficacious among the tools for the study of fibre distinction. Most are made of baked clay or modified potsherds, but occasional examples of stone or bone occur as well. Ethnographic studies provide information on whorls made of other organic materials,[94] but these are missing from the archaeological record, leaving us only to imagine their use and, more importantly for the study of the fibre, their functionality.

Besides their functional role in the production of spun fibre, ethnohistoric accounts,[95] gender studies[96] and research that focuses on the division of labour[97] assign other roles and meanings to these tools. When contextual information is taken into account, spindle whorls are a compelling source for exploring how functionality is intertwined with symbolic meanings.

Large-scale evaluation of spindle whorls shows patterns of changes in form, size and quantity. It is clear that metric changes can be attributed to many different factors; change in raw material preference is only one of the options to explain shifts in functional aspects of spindle whorls. Changes in weaving technology and increase in the variability of desired products might have also influenced their properties. Different types of textiles used to produce garments, tents, carpets, sails and sacks might demand whorls of very different weights and diameters, depending on the thread coarseness, thickness and raw material. Other factors affecting tool characteristics might include changes in labor organization or shifts from subsistence to surplus strategies, from sedentary to mobile lifestyle, or from household to large-scale production. Personal preferences and learning traditions must also be taken into account.

Overall, significant patterns in the metrics of spindle whorls would include changes in size (especially the weight to diameter ratio) and in degree of variability, shown by stronger clustering or wider dispersion.

Even though other categories of finds are underrepresented in comparison to spindle whorls, they nonetheless offer useful evidence to explain technological change. Identifying vertical looms can be predicated on finding loom weights in rows. The limited evidence for loom weights in the Near East before the 3rd millennium BC is an indication that

93 Breniquet 2008.
94 Hochberg 1980.
95 S. D. McCafferty and G. G. McCafferty 1991.
96 Brumfiel 1991; Costin 1996.
97 Barber 1994.

other devices, such as the horizontal or back-strap loom, were prevalent. Unfortunately these rarely leave any trace in the archaeological record.

2.2 Archaeozoological evidence

The analysis of animal bones from archaeological sites provides primary data on the species that people exploited. The most important data are NISP (number of identified specimens), age at death and sex of individuals, morphological variation and anatomical measurements. Statistical evaluation of these data allows conclusions on species frequencies, age and sex profiles as well as variations in body size and body proportions. The results can then be used for diachronic analyses. These methods have been applied for many decades and have the advantage that potentials and limits are quite well understood. The limits are, for example, set by taphonomic loss – an array of factors that reduces the quality of data and the possibilities of interpreting faunal material from archaeological sites.[98]

Still unexplored but urgently needed is research on the genetics of woolly sheep and testing of prehistoric material. It has been recognised that the morphology and size of sheep bones does not necessarily reveal any information about the quality of the sheep's coat (among modern sheep, there are some rather small-sized breeds that bear fine wool). On the other hand it cannot be excluded that in prehistoric periods the change in the coat of sheep was in fact accompanied by differences in features such as body size, proportion and horn forms.[99] This is one hypothesis amongst others that is being investigated in our research.

2.3 Geoarchaeological evidence

Different archives provide complementary information which may be used to reconstruct past landscape conditions. This information is always proxy-based and of indirect nature. Causal links between triggers, effects and processes of landscape development are multidimensional. Therefore, it is only possible to develop models of environmental evolution whereby type, quality and quantity of the data, as well as temporal and spatial scale effects are essential for their respective degree of significance

Archives of detrital sediments such as colluvia, alluvia, or lake sediments provide insights into former environmental conditions. Chemical composition of the sediments and grain size characteristics of the particles give information on erosion and sedimentation processes as well as pre- and post-depositional environmental conditions. If sediments can be dated reliably and if the respective catchment configuration is suitable, amounts of deposited material can be estimated over time. In this way, phases of intensified and reduced morphodynamics can be revealed, but conclusions about specific triggers such as grazing pressure are not possible.[100]

Archives in wet environments such as lake sediments, oxbows and peat bogs may provide pollen records that can be used as tools to detect particular environmental changes. Amount and quality of arboreal pollen indicate the – regional to local – degree of tree cover and forest composition. Together with further proxies such as charcoal accumulation rates and including independent information on climate conditions, processes like forest burning, clearance, or moderate woodland clearing can be detected.[101]

98 O'Connor 2000.
99 Manhart 1998, 98.
100 E.g. Dotterweich 2008; Dreibrodt et al. 2010.
101 E.g. Geantă et al. 2014; Magyari et al. 2012; Marinova et al. 2012.

Generally, grazing favours growth of primary tree species which have strong leaves that are less sensitive to solar insolation, sprout frequently and are able to grow from the stump. Coppicing may also be a reason for the establishment of tree species with abundant sprouts.[102] Herbaceous and woody understorey would be favoured by longer lasting maintenance of wood pasture.[103] Particular indicator species imply environmental conditions that can be associated with certain human activities. *Plantago*, *Rumex*, and *Polygonum*, among others, indicate soil compaction and are characteristic for pasture communities.[104]

The different archives provide information of alternating spatial as well as temporal resolution. The spatial representativeness of detrital sediment archives is fundamentally different from pollen archives. Pollen is normally blown into archives by wind, and wet deposition environments are essential for its preservation. According to Prentice[105] and Bradshaw[106] the size of the archive surface determines catchment scale. Furthermore, major wind directions need to be taken into account, and relief can play an important role for local wind systems so that pollen records of small mountainous lakes may represent vegetation of lower areas to a larger degree than the size of the site would suggest. The type of pollen influences transport,[107] and pollen productivity of plants determines abundance in the sediment record.[108] Thus, anemophilous plants are generally over-represented compared to animal-pollinated ones.[109]

Time lags between occurrence of environmental disturbance, reaction of vegetation composition and corresponding representation in the pollen record may amount to a couple of years but are generally rather short. However, for the establishment of non-indigenous indicator species, for example, a certain threshold must be exceeded and if new environmental conditions are not maintained, the original state may be reached again quickly.

The source of minerogenous material normally originates from the hydraulic catchment. Only if environmental conditions favour wind transport sources may be situated outside of the drainage basin. Depending on the catchment size, sedimentation processes in low-order basins are comparatively simple. However, spatial and temporal interpretation of the sediment records becomes more and more complex with increasing size of the drainage area and the respective complexity of the catchment configuration. Material is sorted by grain size, and amount of washed-in sediments is dependent on overland flow events in the contributing catchment. Intermediate sediment traps in the catchment may lead to time lags between erosion event and time of deposition in the basin.[110]

Colluvial and alluvial sediment archives are components of such cascade-like erosion-deposition systems by themselves. They are semi-closed or open archives, representing storage of high temporal variability where sediment is trapped for a certain amount of time and subsequently transported onwards. The advantage of lake sediments is that they were mostly deposited continuously and thus provide an archive characterized by high temporal resolution. They are thus ideal archives of environmental signals that are driven by climate change and human activities. However, lake sediments are the last member in the sequence of a sediment cascade of a catchment including glaciers, fans, terraces, colluvial deposits, fluvial and lake sediments. Fluvial deposits have the advantage that

102 Ellenberg 1996.
103 Kalis, Merkt, and Wunderlich 2003.
104 Behre 1982; Bottema and Woldring 1990.
105 Prentice 1985.
106 Bradshaw 1988.
107 Bradshaw 1988.
108 Jacobson Jr. and Bradshaw 1981; Prentice 1985.
109 Grimm 1988.
110 E.g. Church and Slaymaker 1989; Hoffmann, Lang, and Dikau 2008, Hoffmann, Thorndycraft, et al. 2010; Verstraeten, Lang, and Houben 2009.

they provide more detailed information on process dynamics and magnitude. Thus, an estimate of realistic magnitudes and frequencies of flood events can only be achieved by integrating information from lake sediments and fluvial deposits of tributaries. Dating and quantification of erosion and transport rates using colluvia or alluvia always include high insecurities.[111]

Pollen records allow conclusions on climate variability and human influence on vegetation over time and thus contribute to an estimation of the degree of herding pressure on past landscapes. However, it is not possible to reveal consequences of such activities on erosion processes. In contrast, minerogenous archive material gives information on erosion and sedimentation processes, but it is difficult to differentiate between climatic and human-induced morphodynamics, and the effects of different human activities are virtually indistinguishable.[112] When integrating several archives and even more when combining different types of archives, the various spatial and temporal scale effects need to be taken into account.

2.4 Written sources

Cuneiform sources pertaining to the socio-economic significance of early Mesopotamian sheep husbandry and the textile industry exist for the Late Uruk and Jemdet Nasr (ca. 3200–2900), Early Dynastic (ca. 2900–2350), Sargonic (2350–2100) and Ur III periods (ca. 2100–2000 BC).[113] The textual documentation can be roughly subdivided into three groups:

(1) Documents from official archives pertain mostly to state-run households and constitute the bulk of our data. They are complemented by (2) economic and legal texts and letters from private archives. (3) A functionally different group of texts includes lexical material (word lists) and literary sources, such as myths, hymns, debate poems, etc.

These texts can be examined on at least two levels: firstly, they present a rich semantic repertoire, in both Sumerian and Akkadian. Terminology includes distinctions among sheep and goats according to varieties, including woolly and fat-tailed sheep as well as 'native' and foreign specimens, sex, age, and breed. Furthermore, they offer a highly differentiated terminology for qualities of wool, skins and other products, with numerous terms designating textiles, clothes, tools and techniques employed in processing wool and manufacturing textiles. They also indicate various professions involved in herding and textile production and their management.

Secondly, analysis of archival contexts informs on the organization of animal husbandry and the textile industry and their embeddedness in the state economy and resource management. Thus cuneiform sources not only enlighten us on virtually all steps of the *chaîne opératoire* from sheep to cloth at various levels of administration but also testify to the socio-economic aspects of husbandry and textile manufacture, when, for example, mention is made of textiles as elements of subsistence in redistributive economies, prestige items, and commercial goods.

Cuneiform sources provide an unprecedented wealth of information on sheep husbandry and the textile industry in early economies and should enable connections of cuneiform data with archaeological, archaeozoological, and iconographic evidence, be it with regard to sheep varieties, breeds, qualities of wool, or clothing. Despite this potential, the exploitation of cuneiform texts is limited by their very nature. First, their geographic

111 Houben et al. 2006; Hinderer 2012.

112 E.g. Bintliff 2002; Kalis, Merkt, and Wunderlich 2003; Butzer 2005; Fiorentino et al. 2013.

113 Since the project focusses on the early cuneiform evidence, the rich sources from the 2nd and 1st millennia are not included.

and chronological distribution is uneven. Second, research on sheep husbandry must account for archival context. While cuneiform sources document husbandry in urban societies, the involvement of non-literate nomadic and semi-nomadic groups is only indirectly attested. Third, problems in lexicography still hamper understanding of the various terms for varieties and breeds of sheep and goats, the tools employed in plucking, shearing and processing wool and hair, the resources themselves, the techniques used in processing raw materials and terminology for textiles and clothes. Finally, cuneiform terminology is often subject to regional and diachronic variation, and information gained from administrative texts is often insufficient for reconstructing the techniques employed.[114]

3 Objectives and methodological approach

Given the fact that animal fibres from the Neolithic, Chalcolithic and Bronze Age are preserved only on rare occasions under special archaeological conditions and even the genetic code of the coat qualities of sheep is not yet known, research on the origin of the woolly sheep by necessity relies primarily on indirect evidence. The aim of this project is to narrow down the beginning of wool production geographically and chronologically via a multi-proxy approach that draws on archaeozoological data, iconography and archaeological artifacts. Archaeobotanical data are also taken into consideration: the exploitation of flax *(Linum usitatissimum)* for both seeds/oil as well as linen is evidenced from the 8th mill. BC onwards.[115] According to recent studies, the use of flax preceded that of wool. Both materials seem to have co-existed during the Later Neolithic, while wool prevailed in more recent times. Unfortunately, there are very few sites that have yielded sheep bones and flax remains in sufficient quantities over a long period of time to allow detailed investigation of such changes.[116]

Assuming intensification of sheep herding, one may expect landscape alteration in terms of changing vegetation composition, opening of woodland communities and trampling effects, culminating in an overall landscape degradation. The effects of grazing on vegetation cover can be ascertained through examination of pollen assemblages.[117] Environmental conditions can be inferred from detrital sediments using geochemical parameters.[118] A synopsis of methods for reconstructing palaeoenvironmental conditions and landscape forming processes can be found in Barsch.[119]

The aim of the present study is to collect and record as much data as possible from sites inhabited within the time span of 7000–2000 BC, covering the areas of southwestern Asia, southeastern and central Europe. Within this framework both the regions where woolly sheep emerged as well as the critical phases when this may have happened are considered.

3.1 Archaeology

The taphonomic loss of textiles and certain kinds of textile tools is a significant obstacle in identifying processes related to the procurement and processing of wool. The oft neglected and underestimated textile tools have usually not been treated in a differentiated fashion.

114 Cf. the evaluations of written sources as opposed to pictorial and material remains by Garcia-Ventura 2006; Breniquet 2010; Garcia-Ventura 2011; Gleba 2011; Breniquet 2012.

115 Karg 2011.

116 Cf. Becker and Kroll 2008.

117 Behre 1982; Bottema and Woldring 1990.

118 Mackereth 1965; Schütt 2004.

119 Barsch 2000.

Rarely have they been published with all the information necessary for analyses such as those undertaken in our project.

Each category of finds demands a specific methodological approach because their potentials for generating conclusions regarding technological change differ. The main categories of indirect evidence can be divided into two large groups based on the type of information they provide. The first group is comprised of tools: (1) spindle whorls, spools and loom weights, (2) bone tools and needles and (3) pattern stamps. These tools are relevant for providing insight into the *chaîne opératoire* of textile production. They can be analysed statistically in terms of their dimensions, making regional or time-relevant technological changes visible and enabling us to detect patterns of change. The other group includes representations that depict the production processes or products: (4) textile imprints and pseudomorphs, (5) attire and iconographic objects. These last two categories help in the reconstruction of traits of early fleece-bearing sheep, cloth and clothing that is no longer preserved, and even textile production techniques.

The interdisciplinary and large-scale, spatio-temporal scope of the project calls for a data survey that is broad in scope and that reveals tendencies, movements and directions, rather than focussing on single site histories. Existing typologies of textile tools serve as a basis for the functional and morphological classification of archaeological objects from the Near East and Europe. Systematization of the data is accomplished by means of an elaborate database specially designed and programmed for the purpose. The protocol follows the principles established by the Centre for Textile Research in Copenhagen.[120]

Statistical analysis of diagnostic objects and their morphological traits establishes a starting point for diachronic patterning throughout the study area. The analyses enable comparisons between site clusters in contexts that are culturally and environmentally specific. In order to elucidate time, space and spread of the new raw material and/or new technologies in textile production, selected sites are chosen as representative of specific regions within the study area.

More than 70 percent of the unpublished finds recorded during the first stage of the research from both Europe and the Near East were classified as spindle whorls. Besides their numerical significance, they can be investigated as a direct link connecting raw material (fibre) and final product (thread). Spindle whorl function can be investigated using an approach based on a series of dimensional analyses, such as weight-diameter ratio, height-diameter ratio and calculations of the momentum or inertia. Comparison of these dimensions serves as a guide from which to infer the spinning techniques that were most likely used, based on their suitability for different types of fibres.[121]

Typological and stylistic traits of the whorls facilitate the tracking of trends among assemblages through time and space, and thereby of changes in textile production technologies. A shift towards animal fibre processing and introduction of a new raw material, may leave only subtle traces in terms of frequency trends. Such shifts may go unrecognized in small-scale sampling. The potential of our approach lies in its large-scale perspective and in its inclusion of multiple strands of evidence.

3.2 Archaeozoology

The number of sites with faunal remains relevant to the domestication of sheep and the emergence of sheep with woolly fleece has grown immensely in recent years. It is the aim of the present study to collect and record as much data as possible from those sites

120 Many thanks to E. Andersson Strand for providing the protocol necessary for data collection on textile tools.

121 Ryder 1968; Smith and Hirth 1988.

inhabited during the time span 7000–2000 BC in southwestern Asia, southeastern and central Europe. Each site is assigned to a time slice of 500 years. If stratigraphic, cultural or archaeological sub-units of sites allow a higher chronological resolution, these are recorded separately. The geographical frame is divided into three areas. Research on southeastern Europe covers a vast area from the Ukraine to Greece and from Hungary to Thrace (Fig. 3). For southwest Asia sites on Cyprus, in Iran, Iraq, Israel, Jordan, Lebanon, Syria, Turkey and Turkmenistan, but also in Armenia, Azerbaijan and Georgia are included. Only data from settlements and tell sites that provide a large enough sample of slaughter and consumption refuse (more than 500 identified mammalian remains) are recorded. Necropoles and places with religious/cultic contexts are not included.

Fig. 3 | Geographical distribution of recorded sites in southeastern Europe (n =149).

For each site a defined set of data is recorded in the database, consisting of four interrelated levels. Level 1 ('site core data') includes the general identification of each site, including name, latitude, longitude, site category, research region, country and geo-region.[122] Level 2 includes basic data that apply to the archaeozoological assemblage such as year of excavation, absolute and relative chronology, culture, publications, the total number of identified mammals and chronological or archaeological sub-units. Level 3 ('site bone

122 Geo-regions have been defined as broad categories to map the archaeozoological finds to geographical areas independent of national boundaries. The assumption that a relation may have existed between geography and sheep husbandry is to be tested. The defined regions in southeast Europe are the Pannonian Plain, the Carpathians, the central Balkan Mountains, the Dinaric Alps, the eastern Adriatic coast, the Ionian Coast, central Greece, Thrace, the Aegean Isles, Crete, the Lower Danube Plain, the Western Black Sea coast, Moldavia and Prut region, Western Ukraine.

data') consists of data related to sheep bones. In level 4 ('*Ovis* bone metrics') measurements of single sheep bones are recorded. The program computes relevant parameters and allows for extraction of various subsets of data as well as graphical illustrations. In the following paragraphs the possibilities and limits of the methods are explained in detail (Tab. 1).

Data recorded	**Explanation**	**Problems / Remarks**
Total NISP of mammals per site	1^{st} rough measure for the size of the assemblage	Useful for the primary sorting of sites to be included or not, not used for statistics
NISP of domestic stock (cattle, pig, ovicaprids)	Importance of sheep / goat within domestic stock	
NISP of sheep and goat	Ratio of sheep to goat	
NISP game[123]	Estimation of the importance of hunting compared to stock-breeding	Antler is subtracted if specified; possible overrepresentation of cervidae if not specified
Age data of sheep (dentition, epiphyses, general)	Monitoring of management strategies via age profiles	
Sex data of sheep (cornu, coxae)	Monitoring of management strategies via sex profiles	Sexing of sheep bones is possible only by horn cores and pelvic bones leading to a very limited no. of data
Pathologies of sheep	Abundance of pathologies can be supporting evidence for changing management strategies	
Shapes of sheep horns	Changes in horn shape are evidence for phenotypical changes that may be related to changes in the coat	
Greatest length (GL) of long bones of sheep (humerus, radius, femur, tibia, metapodiae)	Calculation of withers height according to Teichert (1975); changes in manage-ment strategies are most probably correlated with changes in body size	
Breadth and depth of post cranial elements of sheep (scapula, humerus, radius, femur, tibia, metapodiae, talus, calcaneus)	Calculation of LSI-indices; monitoring of changes of body size and body proportions.	
Archaeobotanical evidence for Linum	Changes in the cultivation of Linum may correspond to changes in sheep husbandry	

Tab. 1 | Evaluation of faunal remains.

123 Only artiodactyl game species are recorded. These are commonly aurochs (*Bos primigenius*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*) plus very rarely occurring single bones of chamois (*Rupicapra rupicapra*), elk (*Alces alces*) and European bison (*Bison bonasus*). Horses have been excluded to avoid the cataracts of the still not solved questions of domestic vs. wild horses especially in the Neolithic.

Most widely used for archaeozoological material are the number of identified specimens (NISP), the minimum number of individuals (MNI) and bone weight. In terms of reliability and comparability, all three parameters have their specific limitations. NISP is the most widely published parameter, and therefore it has been chosen as the main comparative parameter here. Age and sex profiles are based on dentition and the fusing of the epiphyses.[124] They provide us with data for the specific age at which an animal was slaughtered. Another important parameter is the discrimination of sexes, recognised from pelvic bones, skulls and horn cores.[125] The integration of age and sex data into mortality and sex profiles gives clues towards the culling patterns and management strategies with regard to sheep populations. Sheep kept for meat production are slaughtered in a different manner than those kept to produce a maximum amount of wool. The latter will contain a higher number of adult and mature individuals as well as more males or castrates.[126] There is a certain range in the interpretation of age and sex profiles. Only unilateral strategies in life-stock management would lead to a clear pattern in the bone record, something which seldom occurs. Sheep husbandry in prehistory might indeed have been focussed on one product, but other aspects were almost never left aside entirely. This complicates considerably the interpretation of age profiles.[127]

Metric data will likely be the most important and reliable part of our study.[128] The factors for the calculation of withers height of sheep were established by Teichert,[129] the basis of which are completely preserved long bones. Unfortunately those are rarely found, even in large bone assemblages. The sample from Aşaği Pinar offers an illustration: 50 187 mammal remains were identified of which 14 623 belong to ovicaprids, yet the assemblage contains only 12 completely preserved sheep long bones.[130] Fortunately, 715 measurements of the breadth and depth of sheep bones from Aşaği Pinar could be recorded and evaluated (ibid.), taking advantage of the logarithmic size index (LSI[131]). With this method the more frequently preserved breadth and depth distances are compared to a standard animal, allowing the visualisation of the degree of deviation.[132] The LSI-method further allows the monitoring of changes in body proportion. In this study, for the calculation of LSI a set of 23 breadth and depth distances has been chosen from post-cranial elements that have a good chance of being preserved (bones with early fusing epiphyses plus talus and calcaneus), and thus a large amount of data can be expected.

4 Preliminary results and perspectives

In this final section we offer a brief glimpse into some of the preliminary results of our research, taking as an example archaeozoological data from Thrace.

At present, data from 149 sites in eleven European countries have been recorded. Due to separately documented sub-units of multi-period sites, the resulting total consists of 209 individual occupations (Fig. 5). These sites produced 19 260 identified sheep bones. The osteometrical data record consists of 623 values for withers height calculations and 5 952 LSI values. At first sight, this may appear impressive. A closer look, however, reveals that the data are of extremely different quality and resolution. For example the geographical

124 Habermehl 1975; Hüster 1990.
125 Boessneck, Müller, and Teichert 1964.
126 Payne 1973.
127 See also Greenfield 2005, 18–20.
128 Measurements after von den Driesch 1999.
129 Teichert 1975.
130 Benecke (unpublished a).
131 Cf. Meadow 1999.
132 The standard individual used here is a modern female sheep from Bavaria; cf. Manhart 1998, 62.

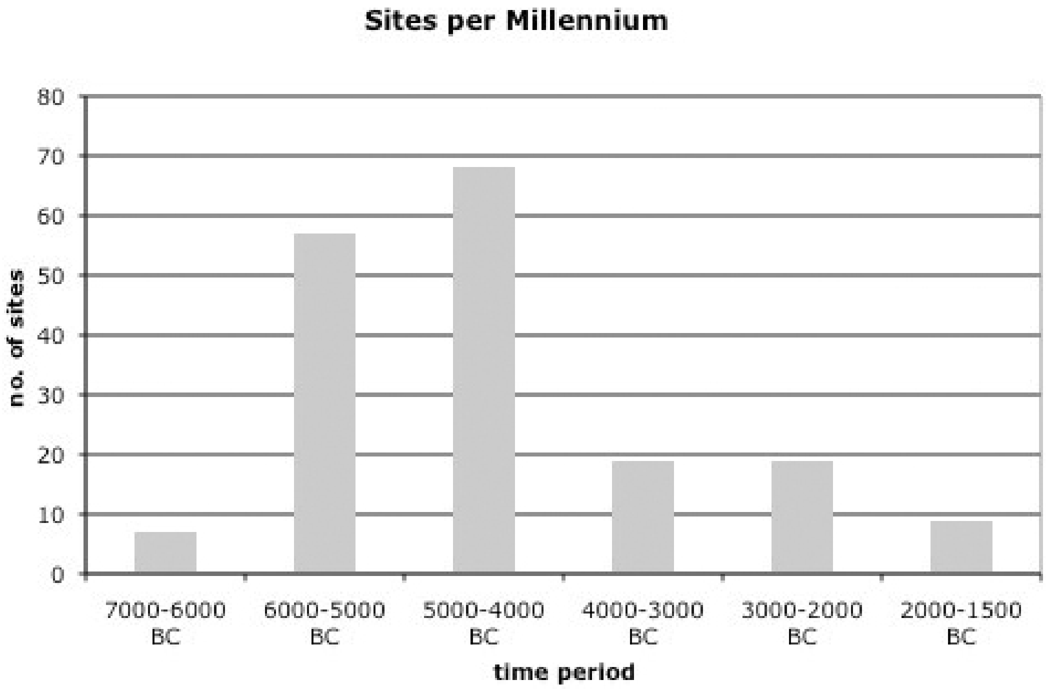

Fig. 4 | Distribution of sites/sub-units with a time span of less than 1000 years (n = 179; above) and less than 500 years (n = 160; below).

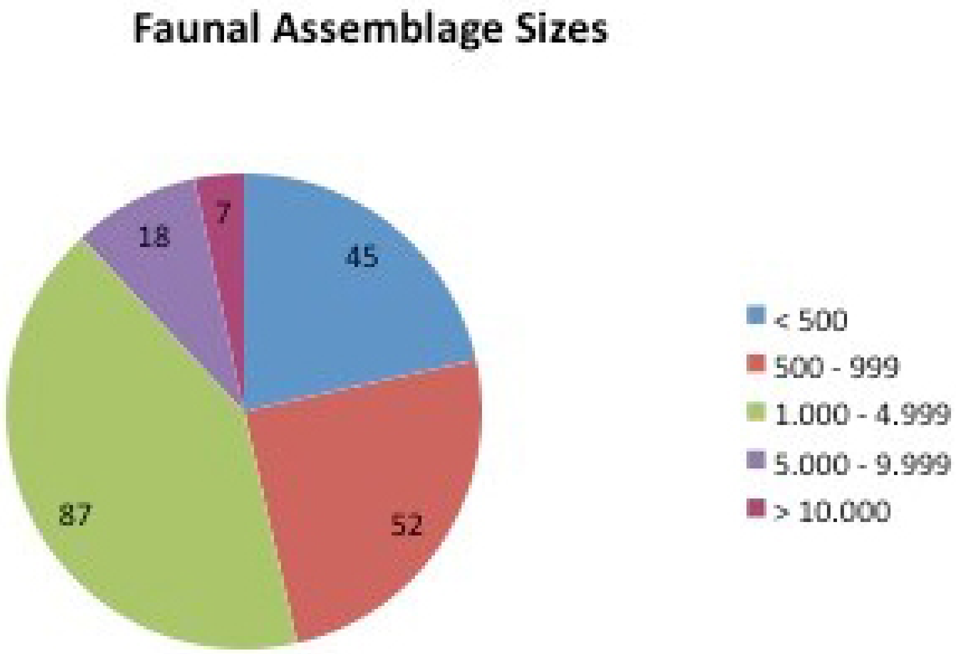

Fig. 5 | Distribution of assemblage size: NISP (number of identified specimens) of domestic stock within all recorded sites/sub-units with more than 500 mammalian remains (n = 209).

distribution of the sites is very uneven (Fig. 3). No less important is the chronological resolution available. Some faunal assemblages have been presented and analysed as bulk samples without precise dating according to contexts or intra-sites phases. However, there are 160 sites or sub-units which could be assigned to time slices of 500 years (Fig. 4). One of the most crucial points is the very uneven distribution of sites over the millennia. There is a large amount of data available for the 6th and 5th millennium BC, whereas for the 4th and 3rd millennia it is rather low (Fig. 4). That is particularly unfortunate, because the later period of time was most probably the most important for the questions raised here.

Site / sub-unit	Dating	NISP domestic stock	n age values	N sex values	N WRH values	N LSI-values	Reference
Karanovo II	6000–5500	3.213	468	/	15	131	Bökönyi and Bartosiewicz 1997
Aşagi Pinar 5	5500–5000	7.904	911	42	4	174	Benecke (unpublished a)
Aşagi Pinar 4	5500–5000	3.682	369	10	1	90	Benecke (unpublished a)
Aşagi Pinar 3	5000–4500	8.548	954	23	4	170	Benecke (unpublished a)
Aşagi Pinar 2	5000–4500	4374	387	14	/	60	Benecke (unpublished a)
Drama-Merdžumekja, Tell K-V	5000–4500	18.244	2.061	67	14	364	Benecke (unpublished b)
Drama-Merdžumekja, Tell K-VI	4500–4000	18.248	1.863	79	10	459	Benecke (unpublished b)
Ezero, FBZ	3000–2500	5.264	/	/	4	99	Georgiev 1979
Kanligeçit	2500–2000	8.486	767	33	/	188	Benecke 2012
Sum		77.963	7.780	268	52	1.735	

Tab. 2 | Sites chosen for preliminary comparative analysis.

For a first impression six sites from Thrace have been chosen. They provide first or at least second class data and cover three millennia (Tab. 2). In the following graphs the sites are grouped in chronological order from older (left) to younger (right) periods (Figs. 6–14). The picture evolving can be summarised as follows. In the 6th and 5th mill. BC, the frequency of game is rather variable, ranging between 15% in the material from Karanovo II, 25–30% in Aşaği Pinar and less than 5% in Drama (Fig. 6). For Aşaği Pinar a continuous decline through the subsequent layers can be observed. The 3rd millennium sites of Ezero and Kanliğeçit contain less than 10% hunted animals. In general, the amount of game seems to be reduced over the millennia.

Within the domestic stock we see the abundance of cattle rising from the 6th to the 5th millennium, staying high in 3rd millennium Ezero and dropping down in Kanliğeçit (Fig. 7). The frequency of ovicaprids declines constantly, with a small peak at Kanliğeçit (Fig. 8). The quantity of pigs remains low (< 15%) over the entire sequence except at Ezero and Kanliğeçit where a considerable increase can be observed (Fig. 9). Sheep dominate over goat in all assemblages (Fig. 10).

As far as the age profiles of sheep/goat are concerned, all assemblages display a generally high number of specimens older than 24 months. However, a different pattern becomes visible in Kanliğeçit and in Drama where the frequencies of mature individuals with medium-worn permanent teeth are considerably higher than in Aşaği Pinar (Fig. 11). The pattern corresponds well with the sex profile (Fig. 12). While ewes comprise regularly more than two-thirds of the flock in Neolithic and Chalcolithic assemblages, the males

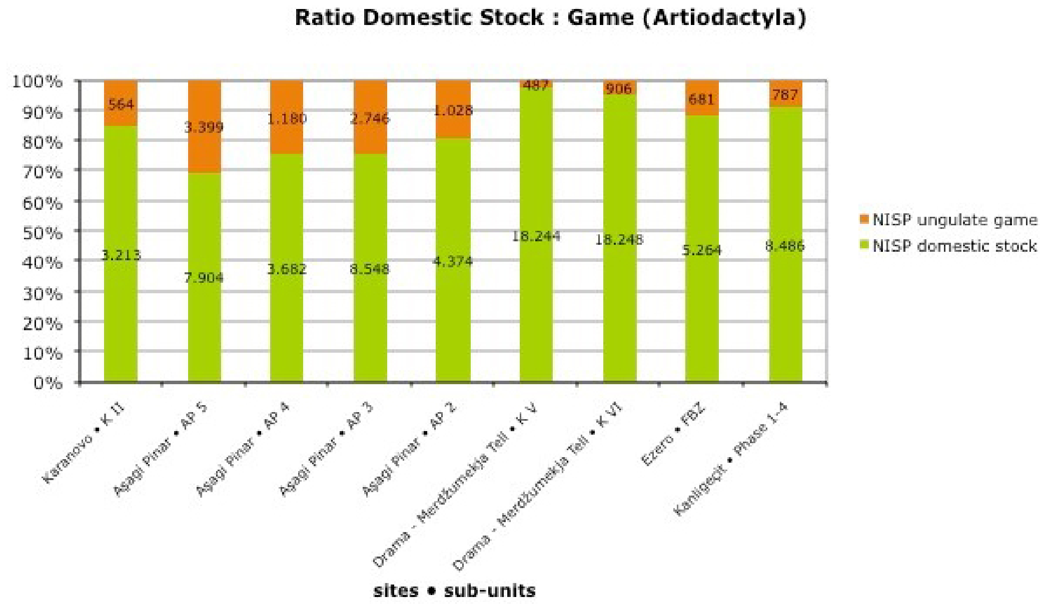

Fig. 6 | Ratio between domestic stock and game through the millennia.

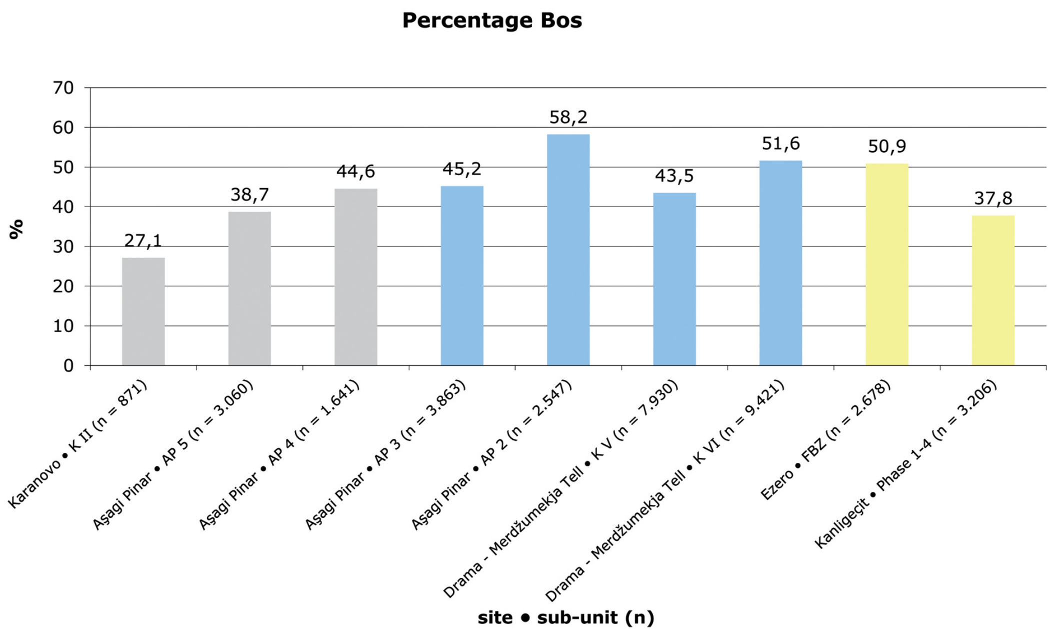

Fig. 7 | Thrace. Frequency of domestic stock through the millennia: *Bos*. Grey: 6th mill. BC, blue: 5th mill. BC, yellow: 3rd mill. BC.

exceed 50 % in Kanliğeçit. It may be surprising, that 5th millennium Drama also yields a high number of individuals with worn teeth (older than two years) while the number of males stays as low as in Aşaği Pinar.

The increase in the withers height of sheep in Early Bronze Age Ezero (Fig. 13) is quite remarkable, although only four values have been gathered. For other sites, too, the quantity of data related to withers height is much too low for any solid interpretation. A more reliable basis can be taken from LSI-values (Fig. 14). Here, the sheep of Bronze Age Ezero and Kanliğeçit are more heavily built compared to those of the 6th and 5th millennium

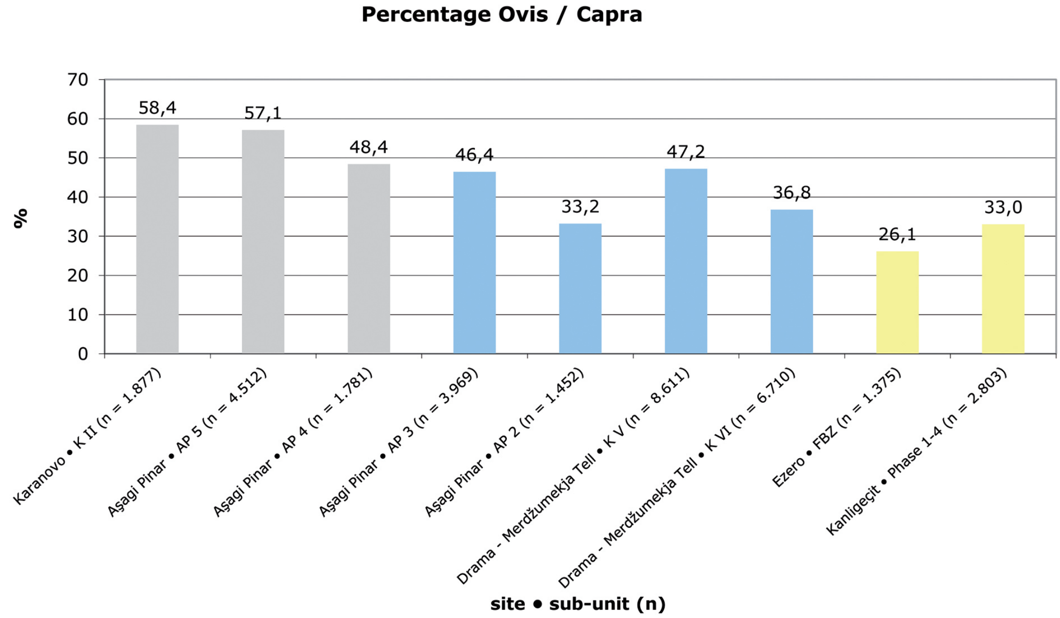

Fig. 8 | Thrace. Frequency of domestic stock through the millennia: *Ovis/Capra*. Grey: 6th mill. BC, blue: 5th mill. BC, yellow: 3rd mill. BC.

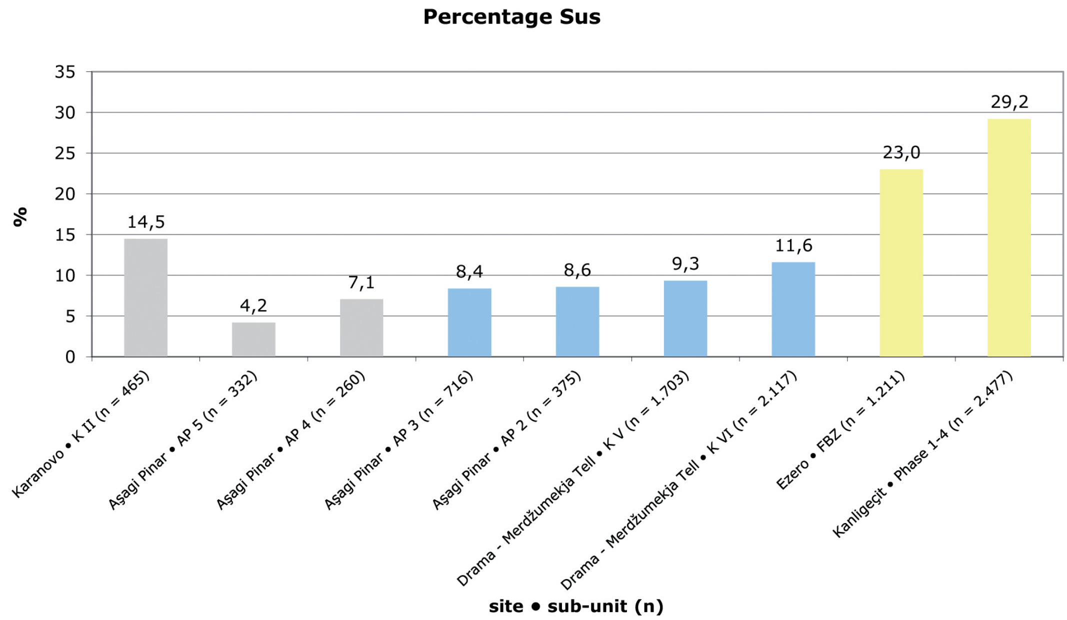

Fig. 9 | Thrace. Frequency of domestic stock through the millennia: *Sus*. Grey: 6th mill. BC, blue: 5th mill. BC, yellow: 3rd mill. BC.

sites, especially Drama. Interestingly the size of the sheep in Aşaği Pinar increases slightly but continuously from AP 5 to AP 2. Equally indicative is the increase in the size variations from the Neolithic/Chalcolithic to the Bronze Age visible in the range of the 10th–90th percentiles (range of 80% of all data) as well as in the maximum ranges. The only site with comparable strongly built sheep and a broad size range is Early Neolithic Karanovo. This may be interpreted as representing early imported sheep that were still closer to the size range of Anatolian wild sheep.

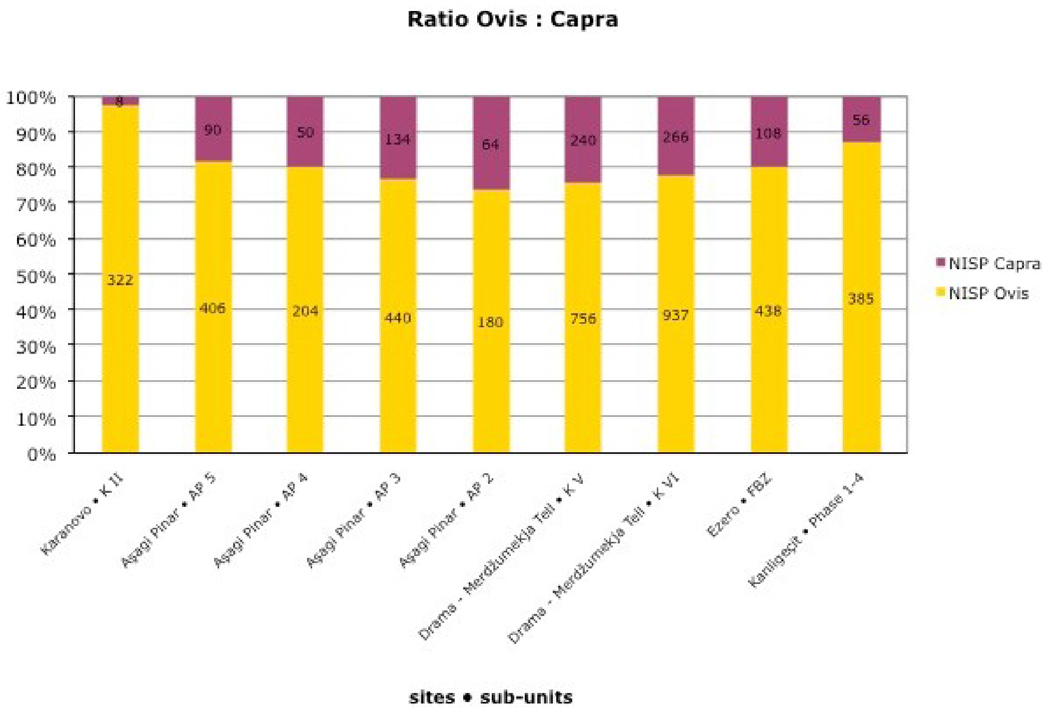

Fig. 10 | Ratio of sheep *vs*. goat through the millennia.

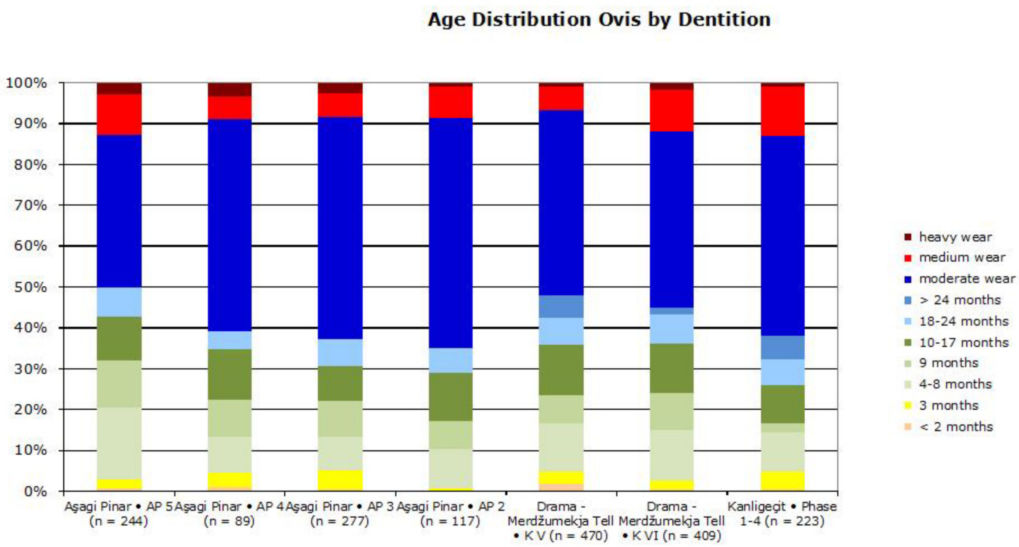

Fig. 11 | Sheep/goat (mostly sheep, cf. Fig. 7): age distribution by dentition (after Hüster 1990, 65).

The economic development in Thrace can be characterised as follows: there is some change in the sheep husbandry of Kanliğeçit (2570–2020 cal BC), demonstrated from a comparably high number of adult and mature individuals and of males (and castrates?), an increase in the variation of size and body shape. This meets the expectation for a specific strategy in herding and thus, a pattern of wool exploitation. Ezero (ca. 3000–2500 BC) may pinpoint the beginning of an economic change, too, as reflected from the increase of body size and stoutness. Unfortunately, there are no age and sex data available and the evidence remains debatable. As has already been mentioned, mixed strategies focussing

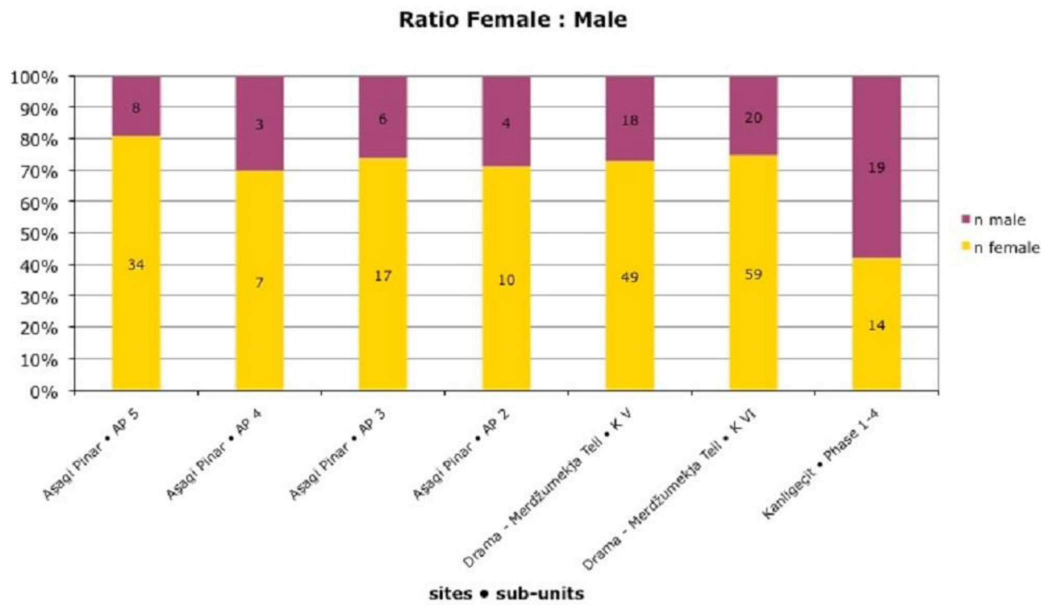

Fig. 12 | Sheep. Ratio females *vs*. males in different time slices.

on meat and milk are not easy to prove from the osteological record. Drama, for example, would in a way be in accordance with milk exploitation (culling of relatively many young and rather old animals). One has to consider that strategies practised within the same period of time might differ from region to region, depending on local environmental conditions and the skill of the people involved. Also difficult to assess is the amount of taphonomic loss that might bias each bone assemblage differently, in particular if we aim at a comparison over larger areas. We have to accept that we never see the full picture. However, it will be a matter of accumulating information to try to get a handle on the sequence of events that led to the keeping of woolly sheep in Europe. Only then may we decide if H. Greenfield[133] was right when he proclaimed for the central Balkans that "the period that shows the most significant shift in the [slaughter] profiles is the Early Bronze Age". This could hold true for Thrace, too.

For the Near East the research situation is in at least some ways dissimilar to that in southeastern Europe. There are more sites with large bone assemblages, most of them well analysed and published in detail. Furthermore, the number of tell sites with long stratigraphic sequences is considerable. They allow a better monitoring of intra-site changes. The comparison of Near Eastern and European sites will offer a promising avenue for interesting results on the history of the woolly sheep.

These first preliminary results of the archaeozoological part of the project have been chosen to illustrate the kind of results we hope to achieve. Equally promising are preliminary metric analyses of spindle whorls, both in Southeastern Europe and the Near East. As has been pointed out above, the interdisciplinary project will not provide direct proofs for the first processing of sheep wool in different regions and periods of Europe and the Near East, which will only be available if future palaeogenetic research identifies the growth of fleece. The projects' objective, however, is to collect and compare available evidence from different disciplines on a large geographical and time scale. This large-scale multiproxy approach is expected to provide an enhanced temporal and spatial resolution for the indirect evidence attainable from published and unpublished sources. In this large-

133 Greenfield 2005, 28.

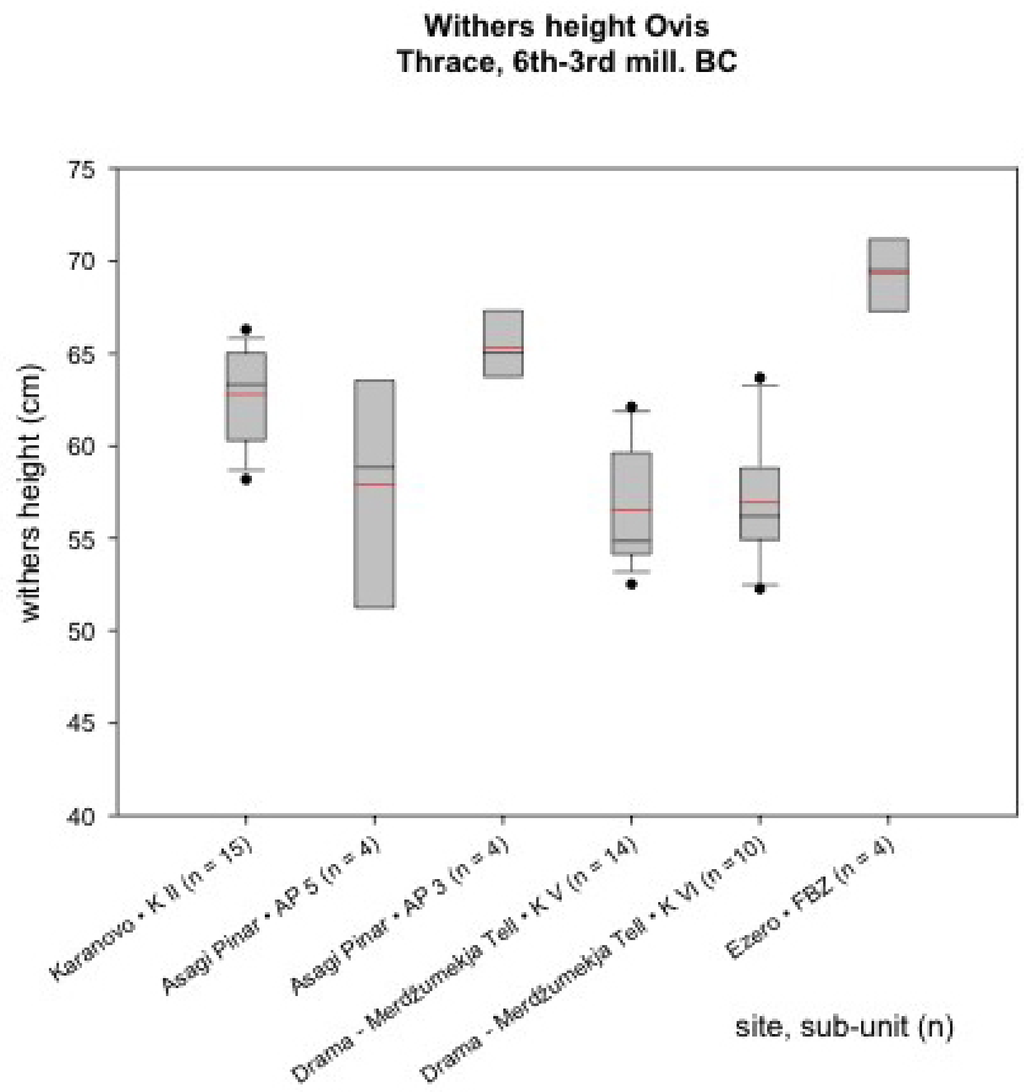

Fig. 13 | Thrace. Sheep. Box-plot of withers height; box = distance 25th–75th quartile with median (black line), whiskers = distance 10th–90th percentile, black dots = outliers, red line = mean value (FBZ = Early Bronze Age).

scale approach, the dynamics and effects of animal fibre production can be expected to become better visible and intelligible.

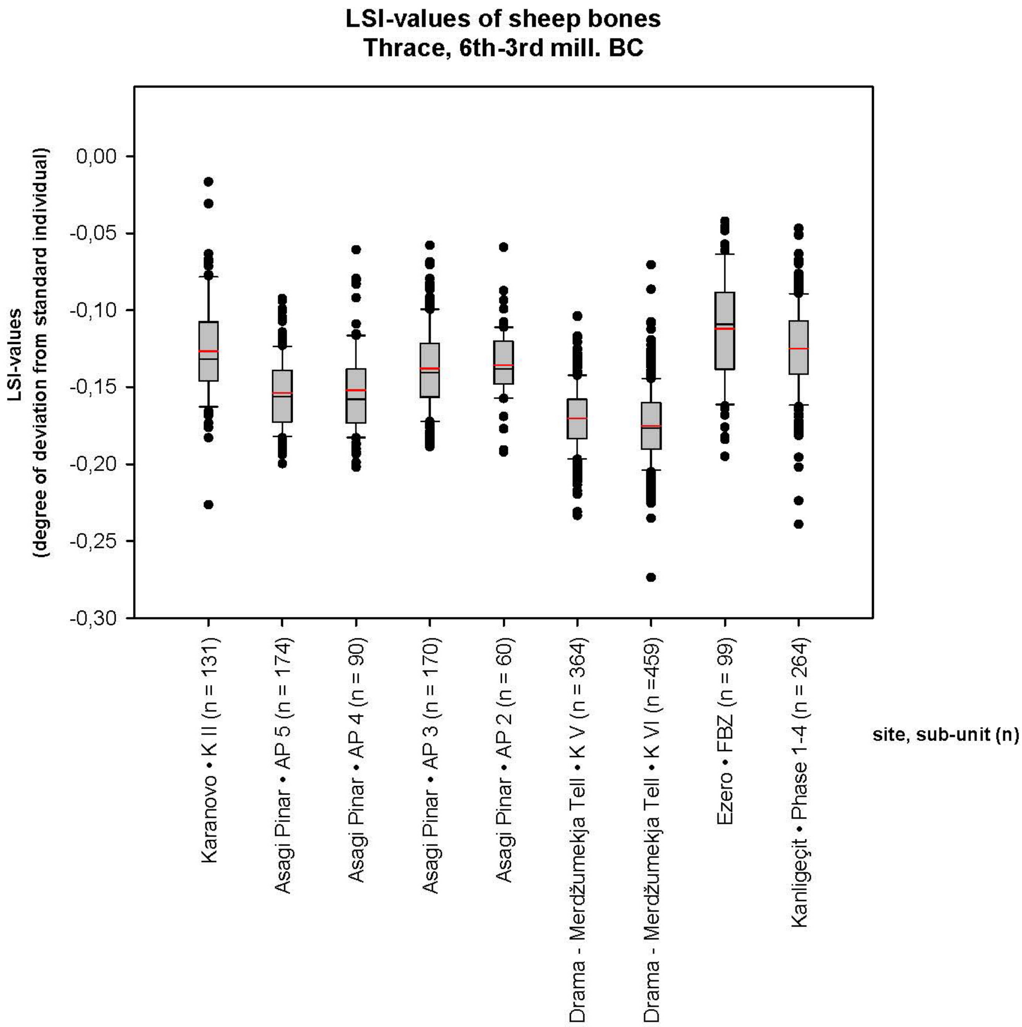

Fig. 14 | Thrace. Sheep. Box-plot of LSI-values; box = distance 25th–5th quartile with median (black line), whiskers = distance 10th–90th percentile, black dots = outliers, red line = mean value (FBZ = Early Bronze Age).

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