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Near Landscapes of the Textile Revolution

It was between the Late Neolithic and the Early Bronze Age when wool was introduced as raw material for textile production. It is expected that this innovation had a comprehensive effect on the socio-economic life of people and their environment. However, little is known about spatio-temporal trajectories of the process and the environmental influences it actually had. The approach presented demonstrates how such a comprehensive and complex research question may be operationalized. Decomposition of the overall process and gathering of information from different fields allows to reconstruct particular aspects of the phenomenon and their diachronic change. Subsequent synthesis enables addressing the overall question. This paper focuses on the role of landscape within the process of wool sheep introduction. Besides covering the particular approach to reconstruct herding-related landscape changes it is shown how deeply different disciplinary approaches are interconnected. Finally, difficulties and constraints of data integration are addressed.

Chalcolithic; Early Bronze Age; Carpathians; human-environment interaction; grazing impact.

1 Background

The use of wool for textile production is a several thousand years old practice. In Mesopotamia vegetal fibres have already been replaced by wool fabrics around 5000 cal yr BP as documented by cuneiform texts.[1] Yet the initial shift in economic strategies may have taken place much earlier: The domestication of wild sheep and goats in eastern Mesopotamia occurred at least between c. 11000 and 10500 cal yr BP.[2] Chessa *et al*. provide genetic evidence for the origin of wool-bearing sheep in south-west Asia and a further spread towards Europe, Africa and the rest of Asia.[3] Sherratt links the introduction of wool-bearing sheep to a complex socio-economic transition process which he calls the "Secondary Products Revolution" taking place during the Chalcolithic period.[4] Even though chronological coherence of this process has been revised the view of a post-Neolithic advent of wool production is commonly accepted.[5] However, little is known about the temporal and spatial spread of wool as a common raw material and triggers and effects of this innovation are still rather vague. The widespread introduction of the wool-bearing sheep and of woolly textiles constitutes a complex of issues which is connected to a variety of research fields. Hence, the interdisciplinary research project "Textile Revolution" was established in which the disciplines of archaeozoology, prehistoric archaeology,

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1 Waetzoldt 1972, 4.
2 Zeder 2008, 11598.
3 Chessa et al. 2009.
4 Sherratt 1981.
5 Greenfield 2010, 29–33.

Near Eastern archaeology, Assyriology and physical geography cooperate to seize these interrelations. Data from different regions between West Asia and Central Europe are compiled to trace temporal and spatial aspects of the introduction of wool-bearing sheep and to infer causal dynamics and socio-environmental effects of the process (Figure 1a): Bone assemblages and particular bone measures give information about exploited animal species and may allow conclusions on herd structures and preferably produced products.[6] Predominant culling of subadults indicates meat production whereas herding of adult animals indicates the use of secondary products. Here, the predominance of female animals indicates milk production whereas prevailing male animals may be an indicator for wool production.[7] These compiled qualitative and semi-quantitative data provide direct information on sheep herding and indirect information on wool production. However, it is not possible to infer numbers about the scale of wool production and environmental causes and effects. Prehistoric textile finds as direct evidences are extremely rare because of the rapid decay of the material. In contrast, textile tools such as loom weights and spindle whorls are normally well preserved. Changes of shape and measures of these tools may relate to changes of production processes indicating the start of wool production.[8] Unfortunately, the link between certain shapes of textile tools and types of processed fibres is not very strong. However, state of preservation and abundance of finds may allow to infer socio-economic information e. g. on the scale of textile production, or division of labor. Iconographic representations of livestock and textile-related scenes such as production processes may provide information on the use of wool fabrics.[9] However, it is hard to differentiate between scenes of very particular practices and scenes of everyday life. Hence, such data do not provide information on scales of production and presumably connected effects on the environment. Written sources are the most precise information about ancient textile production. Exact numbers of herd sizes and amounts of produced textiles are documented in cuneiform texts from Ancient Mesopotamia.[10] Unfortunately, such sources are scarce and only available for a small region and a short time window and reflect only certain parts of foremost elite and institutional strata of ancient society.

The possibility of using the wool of sheep may have induced changes in husbandry including exploitation of formerly unused marginal areas and might have triggered changes in non-sedentary subsistence strategy. Assuming that increasing wool production required intensified sheep husbandry implies that landscape dynamics were increasingly affected by grazing impacts. Increasing grazing pressure ultimately leads to land degradation due to vegetation disturbance and subsequent soil erosion.[11] However, it is a difficult task to precisely attribute human-induced landscape changes to certain palaeo-environmental proxies and to distinguish them from climatically triggered processes. Deducing prehistoric grazing impact of particular animals from palaeo-environmental proxies alone, however, is impossible. Nevertheless, the hypothesis that the introduction of wool-bearing sheep led to increasing landscape disturbances can be tested using geoscientific methods. This addresses the quantitative aspect of the introduction of wool-bearing sheep and contributes to spatial and temporal aspects of the process.

To investigate the prehistoric grazing impact the spatial focus was put on the Carpathian region (Figure 1b). Studies on prehistoric settlement history and cultural development in the Carpathian region have a long research tradition[12]. Parsons presents

6 Payne 1973, 281–282.
7 Payne 1973, 281–282.
8 Rooijakkers 2012, 101, 104.
9 Vila and Helmer 2014, 30–34.
10 Green 1980, 4.
11 Belsky and Blumenthal 1997, 319, 324; Milchunas and Lauenroth 1993, 331–346.
12 E. g., Chapman, Magyari, and Gaydarska 2009; Duffy et al. 2013; Kalicz 1994; Sherratt 1982; Sherratt 1983.

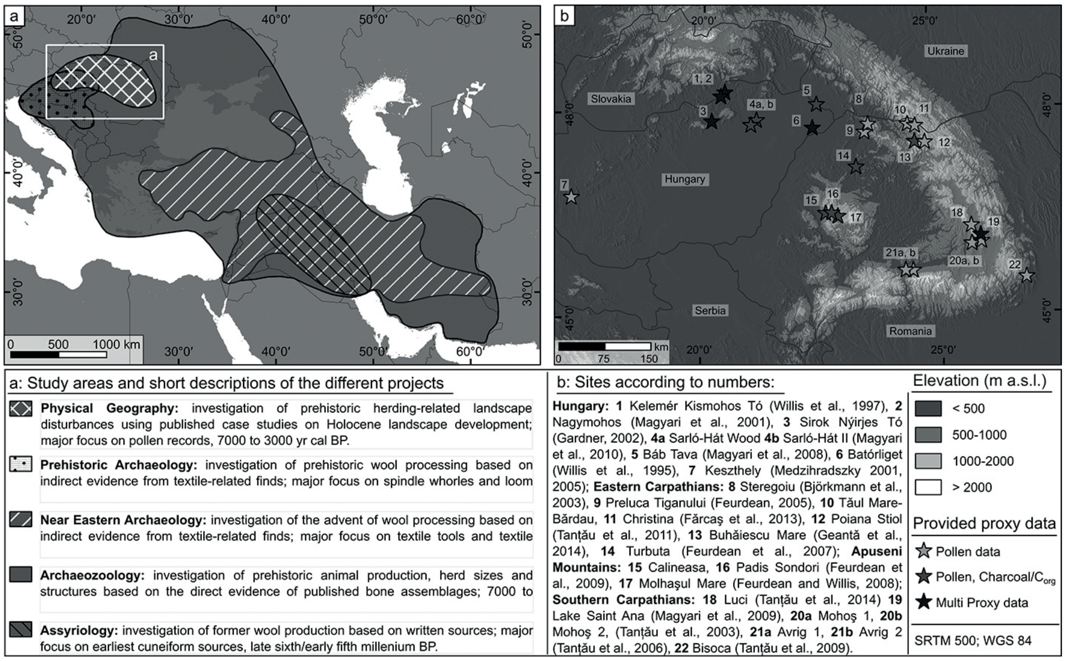

Fig. 1 | Study regions and sites included in the review (see also Tab. 1).

extended considerations about the transformation processes in the Great Hungarian Plain during the Late Chalcolithic[13] and studies on ^{87}Sr-^{86}Sr-ratios in dental enamel of animals and humans provide information on the mobility of people and animals for the post-Neolithic period.[14] Holocene vegetation development in the region is documented by a number of well-dated pollen records. While Holocene landscape development and human-environment interactions in the eastern Mediterranean, as well as in central Europe have been extensively discussed most recently[15], Holocene environmental history of the Carpathian region is discussed only regionally[16], or with significantly different thematic foci[17]. Considering case studies from the Carpathians on a large scale allows to address spatio-temporal trajectories within the region, as well as to relate them to the south-eastern and north-western adjacent regions.

The introduction of wool-bearing sheep and the use of wool for textile production pose integrated questions requiring the integration of aspects referring to social as well as to natural dynamics. Information on herding practices and on the use of wool itself may rather be inferred from archaeozoological, archaeological and textual evidences. However, the assessment of environmental conditions controlling the herding activities and natural dynamics reacting to the changing socio-economic practices are by default addressed by geoscientific work. Hence, to elucidate human-societal-natural interactions such as feed back mechanisms between the natural environment and the spread of wool-bearing sheep and wool as the predominant raw material for textile production, it is inevitable to integrate different disciplines from the humanities as well as from natural sciences. In the presented paper the approach addressing the environment-related aspects of the introduction of the wool-bearing sheep is illustrated. Here, the role of the environment

13 Parsons 2011.
14 Giblin 2009; Giblin et al. 2013; Hoekman-Sites and Giblin 2012.
15 Dotterweich 2008; Dreibrodt, Lubos, et al. 2010; Dusar et al. 2011; Notebaert and Verstraeten 2010.
16 Magyari, Chapman, Fairbairn, et al. 2012; Willis 1997.
17 Feurdean, Spessa, et al. 2012.

is reflected as well as the adoption and operationalisation of the approach is addressed, rather than results of the project.

2 The role of landscape

Animal herding is directly interlaced with environmental as well as socio-economic conditions: Different natural environments provide habitats of alternating suitability for sheep grazing. People arrange different types of land use within a cultivated area based on economic considerations relating environmental conditions and transport costs.[18] Simultaneously, grazing habits of sheep influence the spatial aspects of herding activities. It is hard to evaluate the significance of the different factors determining prehistoric herding patterns. In particular, human habits, decisions and herding practices are difficult to reconstruct for prehistoric times. Therefore, the role of landscape can only be assessed based on general assumptions about the suitability of landscapes for grazing, grazing habits of sheep and theoretical considerations about land use patterns.

2.1 Impact of grazing on the landscape

Environmental factors such as climate, relief, hydraulic regime and vegetation are part of a complex system controlling the suitability of regions for sheep herding and affect the intensity of resulting landscape dynamics; sensitivity and sustainability of landscapes control the thresholds for their reactions. Climatic extreme events, frequently occurring as regional phenomena may trigger landscape reactions abruptly. However, thresholds change in correspondence to changing environmental factors and husbandry. Additionally, the effect of grazing pressure on the degradation of the landscape might occur with a time lag: while increased grazing intensity enhances the vulnerability of landscape and increases risks of soil degradation and soil erosion, the onset of soil degradation and soil erosion processes depends on the occurrence of extreme weather events – drought, storm or rainfall – which exceed thresholds to trigger earth surface processes.[19] Woodland grazing generally inhibits rejuvenation of trees and gives relative advantage to species of primary forests that are able to grow from the stump.[20] Generally, overall plant species richness increases on grazed areas.[21] Impacts of grazing on vegetation and soils on a global scale are discussed by Milchunas and Lauenroth.[22] They conclude that plant species composition shows fast and net primary production shows moderately fast reactions on grazing while the soil nutrient pool reacts slowly, with a considerable time-lag on grazing. The most productive sites show the greatest reduction in net primary production and forests display a generally positive change of net primary production when grazed. Livestock grazing leads to soil compaction and loss of vegetative cover. Subsequently, deteriorated soil structure, decreasing infiltration rates and increasing overland flow enhance soil erosion (Figure 2).[23] However, the impacts of annual weather fluctuations and long-term climatic cycles may exceed herding impacts masking the grazing effects in the sediment archives.[24] Succession processes on sites with poor soils, tending to soil and

18 Thünen 2014, 15–19.
19 E. g., Church and Slaymaker 1989; Hoffmann, Lang, and Dikau 2008, 2034–2039; Hoffmann, Thorndycraft, et al. 2010, 95; Verstraeten et al. 2009, 28–33.
20 Kalis, Merkt, and Wunderlich 2003, 41.
21 Schütz et al. 2003, 185.
22 Milchunas and Lauenroth 1993, 342–346.
23 Belsky and Blumenthal 1997, 324.
24 Hyder 1975, 77–81; Wilson 1989; Milchunas and Lauenroth 1993, 345.

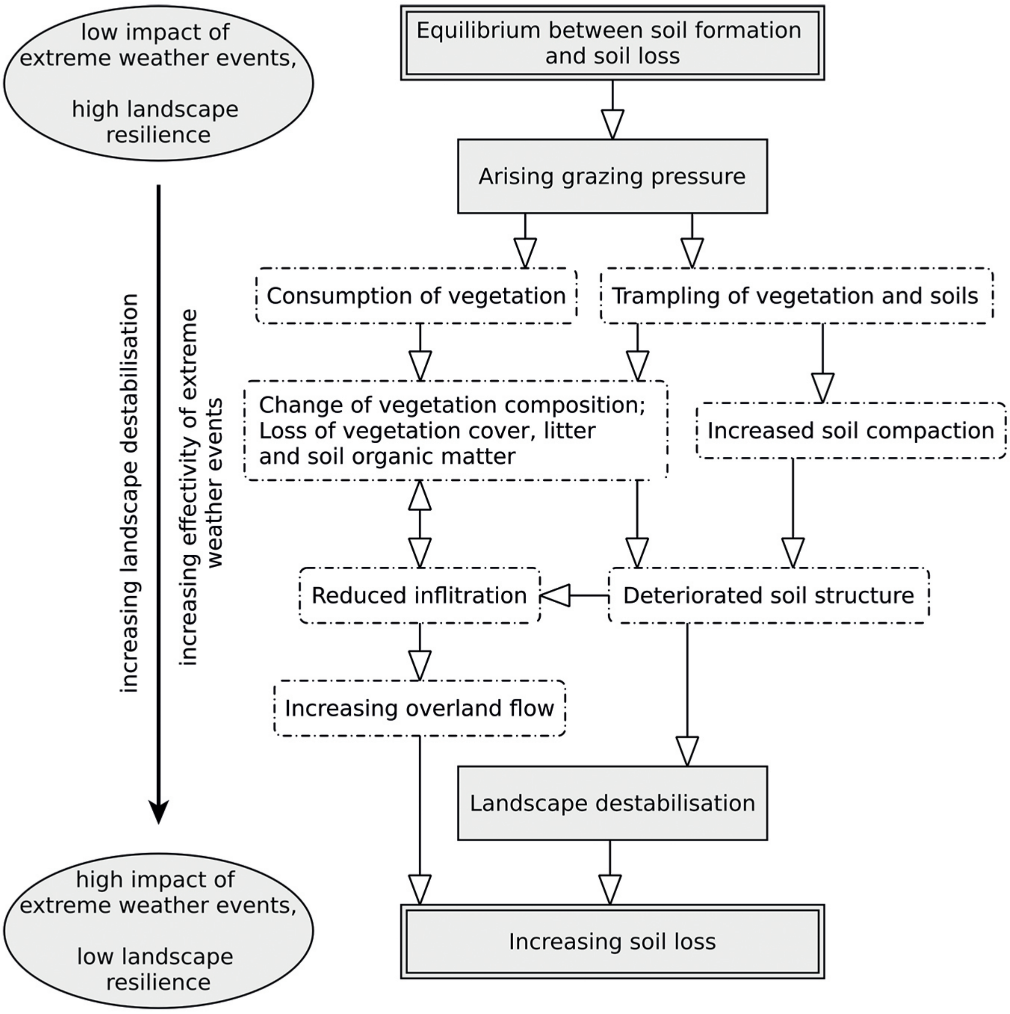

Fig. 2 | Schematic process of landscape degradation due to grazing (modified after Belsky and Blumenthal 1997).

nutrient loss appear to be slower than in sink areas where eroded soils are accumulated.[25] It can be summarized that increasing grazing pressure leads to both, subsequent and synchronous environmental reactions: alteration of vegetation composition is followed by a decrease of vegetation cover and physical and chemical soil deterioration enhances erosion processes.

2.2 Grazing habits of sheep affecting grazing patterns

In general, sheep prefer herbal vegetation whereas goats favor buds and young leaves of trees. However, both may easily adapt to different environmental conditions.[26] Summarising, a variety of case studies Gordon *et al*. document that the complex spatial patterns of herbivore grazing are controlled by the distribution of preferred vegetation.[27] These mechanisms are structured by higher levels of constraints such as distance to water and

25 Risch, Krüsi, and Grämiger 2001, 31.
26 Evangelou, Yiakoulaki, and Papanastasis 2011, 2.
27 Gordon, Hester, and Festa-Bianchet 2004, 1025–1026.

shelter. On coniferous forest range, sheep prefer rich meadows and forests instead of heath land and poor forests, whereas fallow land is most favored.[28] In an Atlantic mountain area of northern Spain sheep prefer grassland instead of heathland and forest.[29] On extensive grassland in north-western Germany, drier and nutrient poor areas are preferred instead of moist and productive habitats.[30] Seasonal differences in grazing patterns are mainly related to changing resource supply.[31] During the night sheep are usually kept in pens where they use to ruminate.[32] In accordance, mountain sheep living in the wild attend shelters such as forests and exposed areas during the night; upper slopes of drainage basins instead of valley bottoms are preferred grazing areas and precipitous slopes and exposed areas are essential escape terrains.[33] This distinctly variable and a circadian rhythm following behavior of sheep living in the wild suggests that for people using simple means of animal keeping a partly vagrant life might have been more suitable for sheep keeping than a sedentary way of life.

2.3 Socio-economic aspects of spatial grazing patterns

Following the classic model of agricultural land use it can be assumed that land consuming economic activities are carried out in the more marginal areas of a settlement whereas labor intensive activities are concentrated immediately around a settlement.[34] Ihse documents that such agricultural structures outlasted for several hundreds of years in southern and central Sweden.[35] With the land use intensification during the younger Funnel Beaker culture in northern Germany around 5000 yr cal BP animals were no longer kept in pens close to houses but woodland pasture started in more distant areas.[36] Finkelstein and Gophna report economic differentiation in the Highlands of Palestine for the Chalcolithic and Early Bronze Age when animal husbandry was concentrated in sparsely populated frontier zones of the highlands; furthermore, the authors consider the occupation of marginal caves during the Chalcolithic to point to the importance of pastoral activities.[37] These examples indicate the significance of peripheral regions for the reconstruction of prehistoric grazing activities.

2.4 Implications for the project design

Vegetation reacts more sensitive to grazing pressure than soil stability[38] and the occurrence of indicator species is more clearly linked to herding impact than soil erosion[39]. Therefore, published pollen records were chosen as the major source of information to trace prehistoric grazing activities and related landscape disturbances. If available, charcoal and geochemical data are included in the discussion of the pollen data. Grazing habits of sheep and socio-economic considerations imply to choose pollen archives that are

28 Warren and Mysterud 1991, 4–5.
29 Mandaluniz, Ruiz, and Oregui 2009, 70.
30 Putfarken et al. 2008, 63.
31 Evangelou, Yiakoulaki, and Papanastasis 2011, 2; Evangelou, Yiakoulaki, and Papanastasis 2014, 210.
32 Evangelou, Yiakoulaki, and Papanastasis 2011, 2; Loridas et al. 2011, 167; Evangelou, Yiakoulaki, and Papanastasis 2014, 211.
33 Gionfriddo and Krausman 1986, 333.
34 Thünen 2014, 12–14.
35 Ihse 1995.
36 Behre 2002, 41–42.
37 Finkelstein and Gophna 1993, 4–6.
38 Milchunas and Lauenroth 1993, 342–346; Belsky and Blumenthal 1997, 324.
39 Behre 1981; Bottema and Woldring 1990; Magyari, Chapman, Fairbairn, et al. 2012.

located in a certain distance from settlement areas. This meets the fact that sediment archives providing well preserved pollen records such as peat bogs or mountain lakes are often located in unsettled environments. However, it has to be considered that these sediment archives often provide only pollen from local source areas. Therefore, impacts of herding activities few kilometres away might not be represented in the archives any more. The temporal resolution and accuracy of the different data sets vary, as well as the spatial representation is heterogeneous. Furthermore, different numbers of proxies indicating herding-related landscape disturbances are published for the different sites. This implies a standardisation of the data as well as a standardized evaluation of prehistoric grazing pressure using a consistent set of proxies. In addition, a temporal and spatial generalisation of the results allows to trace large-scale spatio-temporal trajectories of prehistoric herding indication.

3 enidence of ancient grazing landscapes

Evidences on Holocene landscape conditions and landscape processes in general are provided by environmental archives. However, attributing distinct causes to certain processes in landscape dynamics is highly difficult.[40] Even if catchment configuration is rather simple and the area is archaeologically well investigated, it is hard to directly relate phases of soil erosion to particular human activities as they might appear with a time-lag due to the appearance of the triggering extreme weather event.[41] Phases of landscape destabilisation and soil erosion during prehistoric times are commonly attributed to enhanced field cultivation rather than to animal husbandry.[42] It is therefore not assumed that intensified herding activities during prehistoric times were intense enough to trigger large-scale soil erosion. However, increasing grazing pressure increased the exposure of the landscape to erosion processes and, thus, concurring with extreme weather events might have affected increased erosion rates. On the basis of sediment texture alone a differentiation between soil sediments mobilized due to husbandry from those mobilized due to intensive grazing is not possible. Therefore, the data compilation mainly focuses on studies on Holocene vegetation development, whereas studies on prehistoric soil erosion are considered secondarily.

Increasing grazing pressure is directly reflected in density and composition of the vegetation cover.[43] Pollen, the most appropriate proxy to reconstruct vegetation composition, are preferentially preserved under anoxic conditions. Therefore, most archives providing long sequences of pollen data are lakes, peat bogs, oxbows or waterlogged depressions.[44] Representativity of pollen archives is rather variable. The reliability of the determination of a source area is related to basin size and type of pollen; wind as well as surface runoff control transport distances and directions of pollen transport.[45]

Indicator species may be used to infer environmental conditions and human impacts, although, the natural vegetation of the investigated site always has to be considered.[46] *Polygonum aviculare* and *Plantago major/media* represent ruderal vegetation and *Plantago lanceolata* and *Rumex acetosa/acetosella* represent pasture and meadow communities; these

40 E. g., Bintliff 2002; Butzer 2005; Fuchs 2007; Kalicki et al. 2008; Kalis, Merkt, and Wunderlich 2003.

41 Fuchs, Lang, and Wagner 2004.

42 Dreibrodt and Wiethold 2015, 306, 315.

43 Milchunas and Lauenroth 1993, 331–340.

44 Bernabo and Webb 1977; Buczkó et al. 2009.

45 Bradshaw 1988, 726.

46 Behre 1981, 240–241; Bottema and Woldring 1990; Magyari, Chapman, Fairbairn, et al. 2012, 282–284.

four species are commonly interpreted as indicators for animal herding.[47] The Transylvanian lowlands were covered by extensive forests during the Early and the Middle Holocene.[48] Therefore, it can be assumed that the surroundings of the included sites were naturally forested during the timeslice of interest. Percentages of arboreal and non-arboreal pollen may indicate quantitative vegetation composition representing human impact on vegetation cover.[49] Although arboreal-non-arboreal pollen ratios are not the most appropriate values to trace human impact they are the most used ones.[50] Assuming that grazing significantly alters species composition of a given vegetation community and inducing an increase of plant species, statistical measures such as "rate of change"[51] and "palynological richness"[52] are suitable indicators for potentially herding-related human impact. Charcoal concentrations and charcoal accumulation rates indicate the importance of forest fires; here microscopic charcoal represents regional fires and macroscopic charcoal indicates local and extra-local fires.[53] Including climate proxies into the analysis, human induced woodland burning can be distinguished from natural forest fires.[54]

4 Material

The study is based on a compilation of data from published case studies. Articles included deal with sedimentary archives where human impact and especially herding triggered processes were identified (Table 1). Identifying triggers which released landscape processes as they can be reconstructed from sediment archives underlies high uncertainties. The degree to which proxies indicating human impact are emphasized may depend on the objective of the particular case study. Thus, to compare results of a variety of case studies the primary data have to be evaluated and a re-evaluation will be necessary to assess the published interpretations. Above it has to be considered that the significance of indicator species may vary according to the environmental settings of the site.[55] High temporal precision is required to allow a diachronic and spatially comparative analysis of landscape development. Thus, the focus was put on sediment sequences from wetlands such as peat bogs, mountain lakes and drainless hollows providing sufficient pollen conservation and reliable age-depth modelling. Furthermore, a coherent temporal basis of the proxy data is required. ^{14}C ages were recalibrated using IntCal13[56] and linear age-depth models were calculated applying Clam 2.2[57]. In case a published age-depth model was modified according to a more plausible stratigraphy it was incurred. However, temporal resolution of data records inherently may vary within a particular sediment sequence as well as the quality of temporal representation of different sediment sequences is not homogeneous. Thus, despite precise age depth modelling only tendencies of environmental changes can be inferred from the data and quantitative information is not derived. In order to facilitate the inter-site comparison of results proxy values were summarized and mean values were calculated for 500 years time slices.

47 E. g., Behre 1981, 229, 234–235; Bottema and Woldring 1990; Feurdean, Willis, Parr, et al. 2010, 2203; Magyari, Chapman, Fairbairn, et al. 2012, 283; Marinova et al. 2012, 417.
48 Feurdean, Marinova, et al. 2015, 955–956.
49 Bradshaw 1988, 726–727; Feurdean 2005, 65.
50 Kalis, Merkt, and Wunderlich 2003, 38.
51 Huntley 1992, 185–190.
52 Birks and Line 1992, 2–8.
53 Whitlock and Larsen 2001, 76–95.
54 E. g., Feurdean, Spessa, et al. 2012, 112–123.
55 Behre 1981, 240–241; Behre 1990; Bottema and Woldring 1990; Magyari, Chapman, Fairbairn, et al. 2012, 284.
56 Reimer et al. 2013.
57 Blaauw 2010; The R Project.

Map code	Site	Location	Region*	Depositional environment	Proxies**	References
1	Kelemér Kismohos Tó	48.3371; 20.4256	1	Peat bog in depression	Multi Proxy	Willis et al. 1997; Braun et al. 2005
2***	Nagymohos	48.3404; 20.4308	1	Peat bog in depression	Multi Proxy	Magyari et al. 2001
3	Sirok Nýirjes Tó	47.9391; 20.1872	1	Peat bog in crater	Multi Proxy	Gardner 2002
4a	Sarló-Hát Wood	47.9608; 21.1659	1	Oxbow lake	Pollen, Charcoal/C_{org}	Magyari et al. 2010
4b	Sarló-Hát II	47.9608; 21.1659	1	Oxbow lake	Pollen, Charcoal/C_{org}	Magyari et al. 2010
5	Báb-tava	48.1859; 22.4822	1	Oxbow lake	Pollen, Charcoal/C_{org}	Magyari et al. 2008
6***	Batórliget	47.7725; 22.2689	1	Marsh land	Multi Proxy	Willis et al. 1995
7	Keszthely	46.7705; 17.1973	1	Mire/marsh land	Pollen	Medzihradszky 2001; Medzihradszky 2005
8	Steregoiu	47.8133; 23.5447	2	Silt up crater lake	Pollen	Björkmann et al. 2003
9	Preluca Tiganului	47.8230; 23.5419	2	Peat bog in crater	Pollen	Feurdean 2005
10	Tăul Mare-Bărdau	47.8333; 24.6000	2	Peat bog in cirque	Pollen	Fărcaş et al. 2013
11	Christina	47.8333; 24.6166	2	Peat bog in cirque	Pollen	Fărcaş et al. 2013
12	Poiana Ştiol	47.5856; 24.8165	2	Peat bog in cirque	Pollen	Tanţău et al. 2011
13***	Buhăiescu Mare	47.5884; 24.6431	2	Glacial lake	Pollen, Charcoal/C_{org}	Geantă et al. 2014
14***	Turbuta	47,2564; 23,3123	2	Palaeo-lake	Pollen, Charcoal/C_{org}	Feurdean et al. 2007
15	Călineasa	46.5632; 22.8167	3	Infilled doline	Pollen, Charcoal/C_{org}	Feurdean et al. 2009
16	Padiş Sondori	46.5983; 22.7323	3	Infilled doline	Pollen, Charcoal/C_{org}	Feurdean et al. 2009
17	Molhaşul Mare	46.5899; 22.7641	3	Peat bog	Pollen, Charcoal/C_{org}	Feurdean and Willis 2008
18	Luci	46.2969; 25.7375	4	Peat bog in crater	Pollen	Tanţău et al. 2014
19	Lake Saint Ana	46.1285; 25.9008	4	Crater lake	Multi Proxy	Magyari et al. 2006; Magyari et al. 2009
20a	Mohoş 1	46.1337; 25.9046	4	Peat bog in crater	Pollen	Tanţău et al. 2003
20b	Mohoş 2	46.1337; 25.9046	4	Peat bog in crater	Pollen	Tanţău et al. 2003
21a	Avrig 1	45.7142; 24.3947	4	Peat bog in depression/oxbow	Pollen	Tanţău et al. 2006
21b	Avrig 2	45.7142; 24.3947	4	Peat bog in depression/oxbow	Pollen	Tanţău et al. 2006
22	Bisoca	45.5333; 26.8166	4	Peat bog	Pollen	Tanţău et al. 2009

* regions according to numbers: 1 Hungary, 2 eastern Carpathians, 3 Apuseni mountains, 4 southern Carpathians.
** all studies provide pollen data; the term *multi proxy* refers to studies additionally providing geochemical data.
*** data do not cover the whole study period from 7000 to 3000 yr cal BP due to hiatus

Tab. 1 | List of included sites for assessing mid-Holocene grazing impact on the landscape in the Carpathian region (see also fig. 1).

Secondary indicator species such as *Plantago lanceolata*, *Plantago major/media*, *Poylgonum aviculare* and *Rumex acetosa/acetosella* were extracted as proxies indicating animal herding.[58] Arboreal pollen values were considered as indicators for the density of canopy cover, condoning a high degree of uncertainties due to the large variety of influencing factors.[59] Nevertheless, since sheep prefer open herbaceous grounds[60] it was assumed that increasing herding activities are related to decreasing canopy cover due to woodland cutting and maintained by browsing. Therefore, the analysis was conducted on the basic assumption that with intensified herding pollen values of indicator species increase whereas arboreal pollen values decrease. Both proxies were combined in a fuzzy rule-based system and degrees of herding probability were obtained for 500 years time slices.[61] In addition, available proxies allowing to infer palaeo-environmental conditions such as "rate of change"[62], "palynological richness"[63], charcoal accumulation rates[64] or geochemical indicators[65] were used to validate the results. Spatial representativity of the data is highly variable. Although the majority of included sites are small and reflect local pollen rain, the contribution of extra-local and regional pollen cannot be excluded. To level out this spatial inaccuracy sites were aggregated to trans-regional areas achieving a frame for the spatial comparison of the data (Figure 4).

5 Traces of Prehistoric Grazing Pressure

5.1 Literature review

Palynological case studies from the Carpathian Basin focus on different aspects of Holocene environmental dynamics such as post-glacial succession processes, climate fluctuations, geomorphologic processes shaping landscape and human impact. None of the case studies identifies explicitly human-triggered landscape degradation processes for the mid-Holocene. Referring to modern pollen assemblages the pollen records covering prehistory imply that mid-Holocene grazing impact in the Carpathian region was all over low; even if it is assumed that indicated vegetation disturbance was the result of human impact rather than of climate influences. Nevertheless, at 19 out of 23 included sites authors identify human presence and various economic activities such as animal husbandry, peasant farming and woodland management (Figure 3): During the Late Neolithic, human activities are evident throughout the study area, except in the Apuseni Mountains, where the data do not cover this period. In Hungary, Late Neolithic agricultural activities are indicated at the sites Báb-Tava[66] and Keszthely[67]. Besides arable farming also herding activities are indicated at Sarló-Hát Wood.[68] In the Eastern and in the Southern Carpathians, unspecific human activities are mentioned by the authors.[69] Between 6500 and 4500 yr cal BP human activities are largely reduced throughout the study area: at the sites Sarló-

58 Behre 1981, 233; Bottema and Woldring 1990; Magyari, Chapman, Fairbairn, et al. 2012, 283–284.
59 Gaillard et al. 2010, 488–491.
60 Warren and Mysterud 1991, 4–5; Evangelou, Yiakoulaki, and Papanastasis 2011, 2.
61 Schumacher, Schier, and Schütt (in press), 7–9.
62 Huntley 1992, 185–190.
63 Birks and Line 1992, 2–8.
64 Whitlock and Larsen 2001, 76–95.
65 Boyle 2001; Mackereth 1965; Meyers and Teranes 2001.
66 Magyari, Jakab, et al. 2008, 41.
67 Medzihradszky 2005, 89.
68 Magyari, Chapman, Fairbairn, et al. 2012, 291–296.
69 Tanţău, Reille, de Beaulieu, et al. 2003, 122–123; Tanţău, Reille, Beaulieu, and Fărcaş 2006, 54; Fărcaş et al. 2013, 101.

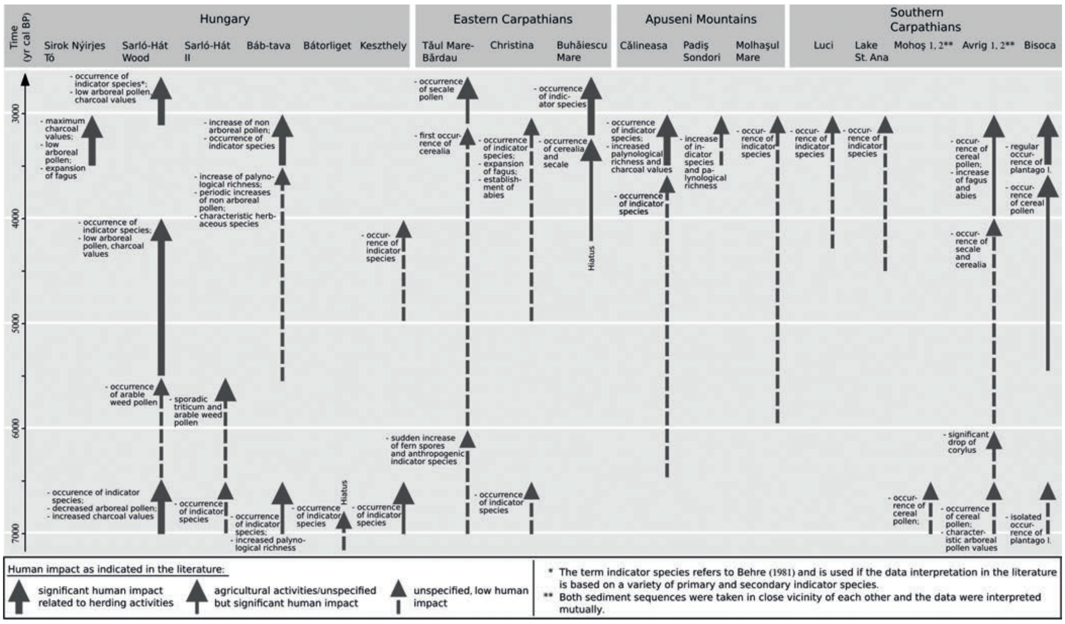

Fig. 3 | Indication of human impact as reported in the included case studies.

Hát Wood and Bisoca impact of grazing and agricultural activities are evident[70], whereas at the sites Báb-Tava, Keszthely, Tăul Mare-Bărdau, Christina, Călineasa, Molhaşul Mare and Avrig only low and unspecific human activities are indicated[71]. During the Bronze Age human impact becomes increasingly significant. At least low anthropogenic activities are evident throughout the study area, except at the sites Mohoş and Keszthely where no human impact is indicated. In Hungary grazing activities are inferred at three sites[72]. In the Eastern Carpathians, the Apuseni Mountains and in the Southern Carpathians herding impact is indicated at one site each.[73] At all other sites human impact is related to arable farming, or authors do not mention specific activities.

5.2 Source criticism

This general overview is in accordance to the commonly accepted view that human activities during the Late Neolithic led to changes in landscape dynamics, whereas during the Chalcolithic human impact on the landscape was less significant and with the onset of the Bronze Age increasing human activities again triggered landscape disturbance.[74] However, not all included case studies focus on human impact on Holocene environmental dynamics and the consideration of indicators for human activities is not homogeneous. Hence, the compilation of published information on human landscape disturbance produces neither a region-wide consistent view about prehistoric human activities in general nor about herding activities in particular. The application of a standardized model

70 Tanţău, Reille, Beaulieu, Fărcaş, and Brewer 2009, 168; Magyari, Chapman, Fairbairn, et al. 2012, 292–293.

71 Medzihradszky 2005, 89; Tanţău, Reille, Beaulieu, and Fărcaş 2006, 54; Feurdean and Willis 2008, 500–501; Magyari, Jakab, et al. 2008, 41–42; Feurdean, Willis, and Astaloş 2009, 973, 975, 978; Fărcaş et al. 2013, 101.

72 Gardner 2002, 551; Magyari, Jakab, et al. 2008, 42; Magyari, Chapman, Fairbairn, et al. 2012, 285–298.

73 Feurdean, Willis, and Astaloş 2009, 975, 978; Tanţău, Reille, Beaulieu, Fărcaş, and Brewer 2009, 168, 170; Geantă et al. 2014, 9–10.

74 E. g., Bintliff 2002, 420; Butzer 2005, 1779–1780.

inferring probabilities of prehistoric herding activities based on pollen data, however, gives a large-scale coherent idea of possible grazing impact. Though, it is admitted that not all the details of the particular case studies can be considered. It is not assumed that a re-evaluation and synthesis of the case studies proposes phases of herding-related degradation processes for any of the studied regions. Yet, by re-evaluating all published data with a uniform thematic focus and using a standardized procedure, prehistoric herding activities can be traced uniformly for the study region.

5.3 Displaying the results of the fuzzy model

The main aspects of the standardized fuzzy model can be summarized as follows: During the Late Neolithic moderate human impact is evident throughout the study area; with the start of the Chalcolithic period probability of herding impact increases significantly in the southern Carpathians and Apuseni Mountains (Figure 4a) and drops abruptly during the transition from Chalcolithic to Bronze Age (Figure 4b); during the Middle Bronze Age herding indication is all over rather low (Figure 4c) while for the Late Bronze Age a high probability of herding impact is evident (Figure 4d).[75] Marinova *et al.* find similar evidences for human impact in the palynological and anthracological records of northern Bulgarian sediment sequences: after a first grazing impact during the Late Neolithic an expansion of light-demanding and riparian trees during the Early Chalcolithic indicates increasing impact of grazing.[76] During the transition from Chalcolithic to Bronze Age there is almost no indication for human impact besides low evidence for pasture activities; between 5200 and 4200 yr cal BP indication for pastoralism again increases and between 3400 and 3200 yr cal BP Marinova *et al.* identify strong evidence for human impact as represented by pollen assemblages.[77]

In contrast, in northern Hungary there is almost no indication for herding impact during the Early Chalcolithic (Figure 4a), whereas the Middle and Late Chalcolithic are characterized by increased herding (Figure 4b). An east-oriented trajectory of herding impact is indicated from Lake Balaton towards the Upper Tisza valley for the period between 5500 and 3000 yr cal BP. According to that, Sherratt describes increasing settlement activities to the east beginning from c. 5500 BP.[78] The sites in the eastern Carpathians are located mostly at sub-alpine altitudes. Pollen records of the sediment sequences indicate locally and temporally differing events of vegetation disturbance. This points to vegetation disturbance due to local human activities. The archives in the eastern Carpathians are situated at marginal locations several tens of kilometres away from known prehistoric settlements. Assuming that vegetation disturbances were caused by human activities this suggests a vagrant rather than a sedentary way of life. However, due to the high elevation of the sites vegetation may have reacted more sensitive to disturbances than the vegetation represented by the pollen records from lowland sites. Therefore, indication of herding impact in this region is rather equivocal compared to sites at lower altitudes in the southern Carpathians and northern Hungary.

Summarizing, it can be stated that the presumed start of wool production between the Late Neolithic and the Early Bronze Age did not have significant impact on landscape dynamics; however, herding-related disturbance of the vegetation cover can be assigned to the relevant time frame. Even though the introduction of wool-bearing sheep might

75 Schumacher, Schier, and Schütt (in press), 7–12.
76 Marinova et al. 2012, 417–421.
77 Marinova et al. 2012, 417–424.
78 Sherratt 1982, 289–290; Sherratt 1983, 37–38.

have been of revolutionary character for the socio-economic life of contemporaries pronounced degradation effects were not connected with this process.

6 Disentangling the Textile Revolution – an inherent bridge between disciplines?

6.1 Data synthesis

The thematic complex of the project holds strong potential for integrated research across humanities and natural sciences. To disentangle the complex process of the introduction of wool-bearing sheep and connected socio-economic as well as environmental changes, data from different fields and of different quality and scales need to be set in relation. Generating these diverse data was achieved by realising interdisciplinary research forming a coherent synergy. General parameters of the investigations such as chronological and spatial foci were determined during the conception phase and have been commonly adjusted during the research. This allowed performing coherent research projects within the different scientific fields, as well as it ensured a constructive data synthesis. Specific aspects related to the introduction of the wool-bearing sheep and to the advent of wool production are addressed by the different projects. Results for the Balkan region, such as shifts of general morphological parameters of spindle whorls will be set in relation to types of textile imprints, the representation of sheep in bone assemblages and the indication of herding-related vegetation disturbance. For Western Asia, the occurrence of sheep-related iconographic representations will be related to written evidence of wool production and both will be compared to the amount of identified sheep species as derived from bone assemblages. Results of the data synthesis from one region may be transferred to another region. E. g., information derived from the combination of wool-, or sheep-related iconographic representations and particular shapes of spindle whorls with detailed information from cuneiform texts, may allow a more accurate interpretation of the same type of proxies from other regions. Similarly, probability of herding activities as derived from pollen records will be supported by information on sheep husbandry as derived from bone assemblages and by information about textile production as derived from textile tools. It is the thematic framework of the introduction of wool-bearing sheep which constitutes the bridge between the different disciplines and respective projects, rather than the complexity of a very particular research issue requiring interdisciplinary research. The results of the independent research projects are coalesced and mutually interpreted to produce a general output of increment value.

6.2 Limits of the approach

The holistic approach of the project inherits certain limits: The large-scale use of wool as raw material for textile production was not a local phenomenon orderly spreading towards the adjacent and farther regions but proceeded with regional and temporal variation.[79] It is therefore important to consider large spatial and temporal scales to reveal processes and mechanisms of this innovation. Large-scale investigations are subject to drawbacks such as significant reduction and generalisation of the data on-hand to be able to cope with the amount of available information. Furthermore, the availability of data becomes more and more heterogeneous with increasing scales of the studied areas and time periods. These problems propagate the more disciplines are comprised within the

79 Greenfield 2010, 35–37, 46–47.

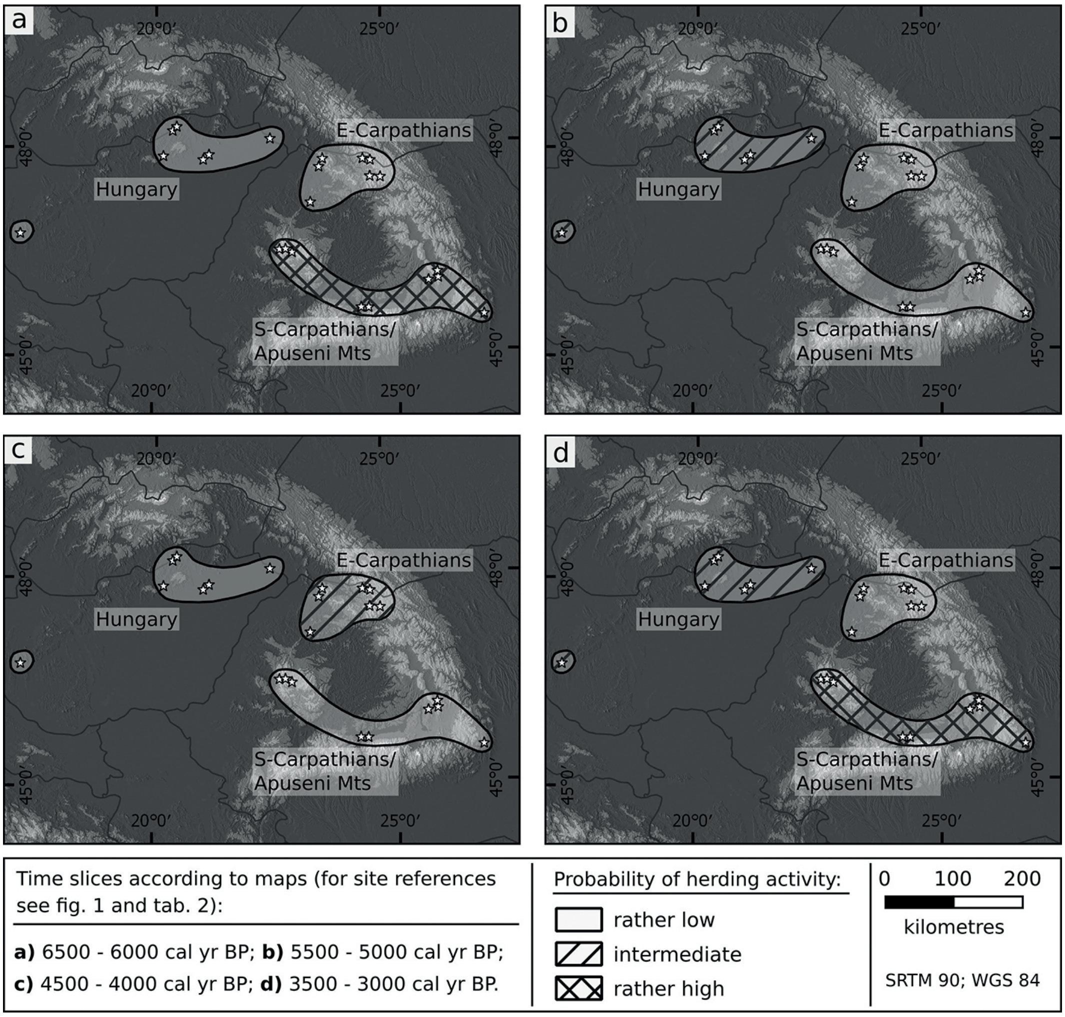

Fig. 4 | Probability of grazing activities in the Carpathian region as inferred from pollen data of published case studies; note that indicated regions do not correspond to catchment areas of the sites.

project. Hence, site specific details may often not be considered and information about wool processing or herding activities provided by the sources of one discipline may lack the support by information from sources of other disciplines. Therefore, the data synthesis will focus on general trends, rather than on local and detailed processes.

Particular obstacles are inherent to the task of addressing landscape reaction to prehistoric grazing pressure. While it is a commonly accepted view that the exploitation of sheep for wool production started between the Late Neolithic and the Early Bronze Age,[80] thresholds of landscape reaction to human activity are highly variable. Hence, land degradation due to large scale wool production and related grazing pressure might have taken place long after the introduction of wool processing; namely when carrying capacities of grazed landscapes were reached and grazing impact could not be compensated any more. Even though the introduction of wool production may have been of revolutionary character regarding socio-economic aspects, the impact of related animal herding on the landscape seems to have started only after 3000 cal yr BP.[81] Furthermore, spatial representation of landscape conditions derived from the different archives are variable and sites with good pollen preservation such as mountain lakes and peat bogs are often

80 Greenfield 2010, 36–37.
81 Schumacher, Schier, and Schütt (in press), 12.

situated in far distance from archaeological sites. If the sites are small and represent only the local vegetation composition, signals of herding-related landscape disturbances from adjacent areas suitable for animal herding, such as gently inclined valley slopes, might not be recorded in the sediments. Thus it is possible that the *de facto* landscape disturbance connected to the introduction of wool processing was stronger than it is indicated in the included sediment records. Nevertheless, by following a semi-quantitative approach the probability of prehistoric herding activities during the time of the presumed advent of wool production could be traced on a trans-regional scale.

References

Behre 1981
Karl-Ernst Behre. "Interpretation of Anthropogenic Indicators in Pollen Diagrams". *Pollen et spores* 23.2 (1981), 225–245.

Behre 1990
Karl-Ernst Behre. "Some Reflections on Anthropogenic Indicators and the Record of Prehistoric Occupation Phases in Pollen Diagrams from the Near East". In *Man's Role in the Shaping of the Eastern Mediterranean Landscape. Balkema, Rotterdam*. Ed. by Sytze Bottema, Gertie Entjes-Nieborg, and Willem van Zeist. Rotterdam: Balkema, 1990, 219–230.

Behre 2002
Karl-Ernst Behre. "Zur Geschichte der Kulturlandschaft Nordwestdeutschlands seit dem Neolithikum". *Bericht der Römisch-Germanischen Kommission* 83 (2002), 39–68.

Belsky and Blumenthal 1997
A. Joy Belsky and Dana M. Blumenthal. "Effects of Livestock Grazing on Stand Dynamics and Soils in Upland Forests of the Interior West". *Conservation Biology* 11.2 (1997), 315–327.

Bernabo and Webb 1977
J. Christopher Bernabo and Thompson Webb. "Changing Patterns in the Holocene Pollen Record of Northeastern North America: A Mapped Summary". *Quaternary Research* 8.1 (1977), 64–96.

Bintliff 2002
John Bintliff. "Time, Process and Catastrophism in the Study of Mediterranean Alluvial History: A Review". *World Archaeology* 33.3 (2002), 417–435.

Birks and Line 1992
H. John B. Birks and John M. Line. "The Use of Rarefaction Analysis for Estimating Palynological Richness from Quaternary Pollen-Analytical Data". *The Holocene* 2.1 (1992), 1–10. DOI: 10.1177/095968369200200101.

Björkman, Feurdean, and Wohlfarth 2003
Leif Björkman, Angelica Feurdean, and Barbara Wohlfarth. "Late-Glacial and Holocene Forest Dynamics at Steregoiu in the Gutaiului Mountains, Northwest Romania". *Review of Palaeobotany and Palynology* 124.1 (2003), 79–111.

Blaauw 2010
Maarten Blaauw. "Methods and Code for 'Classical' Age-Modelling of Radiocarbon Sequences". *Quaternary Geochronology* 5.5 (2010), 512–518. DOI: 10.1016/j.quageo.2010.01.002.

Bottema and Woldring 1990
Sytze Bottema and Henk Woldring. "Anthropogenic Indicators in the Pollen Record of the Eastern Mediterranean". In *Man's Role in the Shaping of the Eastern Mediterranean Landscape*. Ed. by Sytze Bottema, Gertie Entjes-Nieborg, and Willem van Zeist. Rotterdam: Balkema, 1990, 231–264.

Boyle 2001
J. F. Boyle. "Inorganic Geochemical Methods in Palaeolimnology". In *Tracking Environ-*

mental Change Using Lake Sediments. Ed. by William M. Last and John P. Smol. Vol. 2: Physical and Geochemical Methods. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2001, 83–141.

Bradshaw 1988
Richard H. W. Bradshaw. "Spatially-Precise Studies of Forest Dynamics". In *Vegetation History*. Ed. by B. Huntley and T. Webb III. Vol. 7. Handbook of Vegetation Science. Springer Netherlands, 1988, 725–751. http://dx.doi.org/10.1007/978-94-009-3081-0_20.

Braun et al. 2005
Mihály Braun, Pál Sümegi, Albert Tóth, Katherine J. Willis, Imre Szalóki, Zita Margitai, and Andrea Somogyi. "Reconstruction of long-term Environmental Changes at Kelemer-Kis-Mohos-Tó". In *Environmental Archaeology in North-eastern Hungary*. Ed. by Erika Gál, Imola Juhász, and Pál Sümegi. Vol. 19. Varia Archaeologica Hungarica. Budapest, 2005, 25–38.

Buczkó et al. 2009
Krisztina Buczkó, Enikő K. Magyari, Peter Bitušik, and Agnieszka Wacnik. "Review of Dated Late Quaternary Palaeolimnological Records in the Carpathian Region, East-Central Europe". *Palaeolimnological Proxies as Tools of Environmental Reconstruction in Fresh Water* (2009), 3–28. DOI: 10.1007/978-90-481-3387-1_2.

Butzer 2005
Karl W. Butzer. "Environmental History in the Mediterranean World: Cross-Disciplinary Investigation of Cause-and-effect for Degradation and Soil Erosion". *Journal of Archaeological Science* 32.12 (2005), 1773–1800.

Chapman, Magyari, and Gaydarska 2009
John Chapman, Enikö K. Magyari, and Bisserka Gaydarska. "Contrasting Subsistence Strategies in the Early Iron Age? – New Results from the Alföld Plain, Hungary, and the Thracian Plain, Bulgaria". *Oxford Journal of Archaeology* 28.2 (2009), 155–187.

Chessa et al. 2009
Bernardo Chessa, Filipe Pereira, Frederick Arnaud, Antonio Amorim, Félix Goyache, Ingrid Mainland, R. Kao Kao, Josephine M. Pemberton, Dario Beraldi, Michael J. Stear, Alberto Alberti, Marco Pittau, Leopoldo Iannuzzi, Mohammad H. Banabazi, Rudovick R. Kazwala, Ya-ping Zhang, Juan J. Arranz, Bahy A. Ali, Zhiliang Wang, Metehan Uzun, Michel M. Dione, Ingrid Olsaker, Lars-Erik Holm, Urmas Saarma, Sohail Ahmad, Nurbiy Marzanov, Emma Eythorsdottir, Martin J. Holland, Paolo Ajmone-Marsan, Michael W. Bruford, Juha Kantanen, Thomas E. Spencer, and Massimo Palmarini. "Revealing the History of Sheep Domestication Using Retrovirus Integrations". *Science* 324.5926 (2009), 532–536. DOI: 10.1126/science.1170587.

Church and Slaymaker 1989
Michael Church and Olav Slaymaker. "Disequilibrium of Holocene Sediment Yield in Glaciated British Columbia". *Nature* 337.6206 (1989), 452–454.

Dotterweich 2008
Markus Dotterweich. "The History of Soil Erosion and Fluvial Deposits in Small Catchments of Central Europe: Deciphering the Long-Term Interaction between Humans and the Environment – A Review". *Geomorphology* 101.1 (2008), 192–208.

Dreibrodt, Lubos, et al. 2010
Stefan Dreibrodt, Carolin Lubos, Birgit Terhorst, Bodo Damm, and Hans-Rudolf Bork. “Historical Soil Erosion by Water in Germany: Scales and Archives, Chronology, Research Perspectives”. *Quaternary International* 222.1 (2010), 80–95.

Dreibrodt and Wiethold 2015
Stefan Dreibrodt and Julian Wiethold. “Lake Belau and its Catchment (Northern Germany): A Key Archive of Environmental History in Northern Central Europe since the onset of Agriculture”. *The Holocene* 25.2 (2015), 296–322.

Duffy et al. 2013
Paul R. Duffy, William A. Parkinson, Attila Gyucha, and Richard W. Yerkes. “Coming Together, Falling Apart A Multiscalar Approach to Prehistoric Aggregation and Interaction on the Great Hungarian Plain”. In *From Prehistoric Villages to Cities: Settlement Aggregation and Community Transformation*. Ed. by Jennifer Birch. New York: Routledge, 2013, 44–62.

Dusar et al. 2011
Bert Dusar, Gert Verstraeten, Bastiaan Notebaert, and Johan Bakker. “Holocene Environmental Change and its Impact on Sediment Dynamics in the Eastern Mediterranean”. *Earth-Science Reviews* 108.3 (2011), 137–157.

Evangelou, Yiakoulaki, and Papanastasis 2011
Christakis Evangelou, Maria Yiakoulaki, and Vasilios Papanastasis. “Seasonal Changes in Grazing Behavior of Sheep and Goats in Communal Mediterranean Rangelands of Northern Greece”. In *Grassland Farming and Land Management Systems in Mountainous Regions. Proceedings of the 16th Symposium of the European Grassland Federation, Gumpenstein, Austria, 29th–31st August, 2011*. Agricultural Research and Education Center (AREC) Raumberg-Gumpenstein, 2011, 341–343.

Evangelou, Yiakoulaki, and Papanastasis 2014
Christakis Evangelou, Maria Yiakoulaki, and Vasilios Papanastasis. “Spatio-Temporal Analysis of Sheep and Goats Grazing in Different Forage Resources of Northern Greece”. *Hacquetia* 13.1 (2014), 1–9.

Fărcaş et al. 2013
Sorina Fărcaş, Ioan Tanţău, Marcel Mîndrescu, and Bogdan Hurdu. “Holocene Vegetation History in the Maramureş Mountains (Northern Romanian Carpathians)”. *Quaternary International* 293 (2013), 92–104.

Feurdean 2005
Angelica Feurdean. “Holocene Forest Dynamics in Northwestern Romania”. *The Holocene* 15.3 (2005), 435–446.

Feurdean and Willis 2008
Angelica Feurdean and Katherine J. Willis. “The Usefulness of a Long-Term Perspective in Assessing Current Forest Conservation Management in the Apuseni Natural Park, Romania”. *Forest Ecology and Management* 256.3 (2008), 421–430.

Feurdean, Willis, Parr, et al. 2010
Angelica Feurdean, Katherine J. Willis, Catherine L. Parr, Ioan Tanţău, and Sorina Fărcaş. “Post Glacial Patterns in Vegetation Dynamics in Romania: Homogenization or Differentiation?” *Journal of Biogeography* 37.11 (2010), 2197–2208.

Feurdean, Willis, and Astaloş 2009
Angelica Feurdean, Katherine J. Willis, and Ciprian Astaloş. "Legacy of the Past Land-Use Changes and Management on the 'Natural' Upland Forest Composition in the Apuseni Natural Park, Romania". *The Holocene* 19.6 (2009), 967–981.

Feurdean, Mosbrugger, et al. 2007
Angelica Feurdean, Volker Mosbrugger, Bogdan P. Onac, Victor Polyak, and Daniel Veres. "Younger Dryas to Mid-Holocene Environmental History of the Lowlands of NW Transylvania, Romania". *Quaternary Research* 68.3 (2007), 364–378.

Feurdean, Spessa, et al. 2012
Angelica Feurdean, Allan Spessa, Enikő Magyari, Katherine J. Willis, Daniel Veres, and Thomas Hickler. "Trends in Biomass Burning in the Carpathian Region over the last 15,000 Years". *Quaternary Science Reviews* 45 (2012), 111–125.

Feurdean, Marinova, et al. 2015
Angelica Feurdean, Elena Marinova, Anne B. Nielsen, Johan Liakka, Daniel Veres, Simon M. Hutchinson, Mihaly Braun, Alida TimarGabor, Ciprian Astalos, and Volker Mosburgger. "Origin of the Forest Steppe and Exceptional Grassland Diversity in Transylvania (Central-Eastern Europe)". *Journal of Biogeography* 42.5 (2015), 951–963.

Finkelstein and Gophna 1993
Israel Finkelstein and Ram Gophna. "Settlement, Demographic, and Economic Patterns in the Highlands of Palestine in the Chalcolithic and Early Bronze Periods and the Beginning of Urbanism". *Bulletin of the American Schools of Oriental Research* 289 (1993), 1–22. DOI: 10.2307/1357359.

Fuchs 2007
Markus Fuchs. "An Assessment of Human Versus Climatic Impacts on Holocene Soil Erosion in NE Peloponnese, Greece". *Quaternary Research* 67.3 (2007), 349–356.

Fuchs, Lang, and Wagner 2004
Markus Fuchs, Andreas Lang, and Günther A. Wagner. "The History of Holocene Soil Erosion in the Phlious Basin, NE Peloponnese, Greece, Based on Optical Dating". *The Holocene* 14.3 (2004), 334–345.

Gaillard et al. 2010
Marie-José Gaillard, Shinya Sugita, Florence Mazier, A.-K. Trondman, Anna Brostrom, Thomas Hickler, Jed O. Kaplan, Erik Kjellström, Ulla Kokfelt, Petr Kunes, C. Lemmen, P. Miller, J. Olofsson, A. Poska, M. Rundgren, B. Smith, G. Strandberg, R. Fyfe, A. B. Nielsen, T. Alenius, L. Balakauskas, L. Barnekow, H. J. B. Birks, A. Bjune, L. Björkman, T. Giesecke, K. Hjelle, L. Kalnina, M. Kangur, W. O. van der Knaap, T. Koff, P. Lagerås, M. Latałowa, M. Leydet, J. Lechterbeck, M. Lindbladh, B. Odgaard, S. Peglar, U. Segerström, H. von Stedingk, and H. Seppä. "Holocene Land-Cover Reconstructions for Studies on Land Cover-Climate Feedbacks". *Climate of the Past* 6.4 (2010), 483–499. DOI: 10.5194/cp-6-483-2010.

Gardner 2002
Adam R. Gardner. "Neolithic to Copper Age Woodland Impacts in Northeast Hungary? Evidence from the Pollen and Sediment Chemistry Records". *The Holocene* 12.5 (2002), 541–553.

Geantă et al. 2014
Anca Geantă, Mariusz Gałka, Ioan Tanţău, Simon M. Hutchinson, Marcel Mîndrescu, and Angelica Feurdean. “High mountain Region of the Northern Romanian Carpathians Responded Sensitively to Holocene Climate and Land Use Changes: A Multi-Proxy Analysis”. *The Holocene* 24.8 (2014), 944–956.

Giblin 2009
Julia Irene Giblin. “Strontium Isotope Analysis of Neolithic and Copper Age Populations on the Great Hungarian Plain”. *Journal of Archaeological Science* 36.2 (2009), 491–497.

Giblin et al. 2013
Julia I. Giblin, Kelly J. Knudson, Zsolt Bereczki, György Pálfi, and Ildikó Pap. “Strontium Isotope Analysis and Human Mobility during the Neolithic and Copper Age: A Case Study from the Great Hungarian Plain”. *Journal of Archaeological Science* 40.1 (2013), 227–239.

Gionfriddo and Krausman 1986
James P. Gionfriddo and Paul R. Krausman. “Summer Habitat Use by Mountain Sheep”. *The Journal of Wildlife Management* (1986), 331–336.

Gordon, Hester, and Festa-Bianchet 2004
Iain J. Gordon, Alison J. Hester, and Marco Festa-Bianchet. “Review: the Management of Wild Large Herbivores to Meet Economic, Conservation and Environmental Objectives”. *Journal of Applied Ecology* 41.6 (2004), 1021–1031.

Green 1980
Margaret W. Green. “Animal Husbandry at Uruk in the Archaic Period”. *Journal of Near Eastern Studies* 39.1 (1980), 1–35.

Greenfield 2010
Haskel J. Greenfield. “The Secondary Products Revolution: the Past, the Present and the Future”. *World Archaeology* 42.1 (2010), 29–54.

Hoekman-Sites and Giblin 2012
Hanneke A. Hoekman-Sites and Julia I. Giblin. “Prehistoric Animal Use on the Great Hungarian Plain: A Synthesis of Isotope and Residue Analyses from the Neolithic and Copper Age”. *Journal of Anthropological Archaeology* 31.4 (2012), 515–527.

Hoffmann, Lang, and Dikau 2008
Thomas Hoffmann, Andreas Lang, and Richard Dikau. “Holocene River Activity: Analysing 14C-dated Fluvial and Colluvial Sediments from Germany”. *Quaternary Science Reviews* 27.21–22 (2008), 2031–2040. DOI: 10.1016/j.quascirev.2008.06.014.

Hoffmann, Thorndycraft, et al. 2010
Thomas Hoffmann, Varyl R. Thorndycraft, Anthony G. Brown, Tom J. Coulthard, Brahim Damnati, Vishwas S. Kale, Hans Middelkoop, Bastiaan Notebaert, and Des E. Walling. “Human impact on Fluvial Regimes and Sediment Flux during the Holocene: Review and Future Research Agenda”. *Global and Planetary Change* 72.3 (2010), 87–98.

Huntley 1992
Brian Huntley. "Rates of Change in the European Palynological Record of the last 13 000 Years and their Climatic Interpretation". *Climate Dynamics* 6.3-4 (1992), 185–191.

Hyder 1975
Donald N. Hyder. *Ecological Responses of Native Plants and Guidelines for Management of Shortgrass Range*. United States Department of Agriculture Agricultural Research Service Technical Bulletin 1503. Washington, D.C., USA: Agricultural Research Service, US Dept. of Agriculture, 1975.

Ihse 1995
Margareta Ihse. "Swedish Agricultural Landscapes – Patterns and Changes during the Last 50 Years, Studied by Aerial Photos". *Landscape and Urban Planning* 31.1-3 (1995), 21–37. DOI: 10.1016/0169-2046(94)01033-5.

Kalicki et al. 2008
Tomasz Kalicki, Siarhey Sauchyk, Gilberto Calderoni, and Galina Simakova. "Climatic Versus Human Impact on the Holocene Sedimentation in River Valleys of Different Order: Examples from the Upper Dnieper Basin, Belarus". *Quaternary International* 189.1 (2008), 91–105.

Kalicz 1994
Nándor Kalicz. *Wenden des Spätneolithikums im Oberen Theißgebiet*. A Nyíregyházi Jósa András Múzeum Évkönyve (Jahrbuch des Jósa András Museums) 26. Nyíregyháza, 1994, 263–290.

Kalis, Merkt, and Wunderlich 2003
Arie J. Kalis, Josef Merkt, and Jürgen Wunderlich. "Environmental changes during the Holocene Climatic Optimum in Central Europe-Human Impact and Natural Causes". *Quaternary Science Reviews* 22.1 (2003), 33–79.

Loridas et al. 2011
Athanasios Loridas, Ioannis Mountousis, Christos Roukos, Maria Yiakoulaki, and Kostantinos Papanikolaou. "Grazing Behavior of the Greek Breed of Sheep» Serres «in Lowland and Mountainous Pastures". *Archiv für Tierzucht – Archives of Animal Breeding* 54.2 (2011), 165–176.

Mackereth 1965
F. J. H. Mackereth. "Chemical Investigation of Lake Sediments and their Interpretation". *Proceedings of the Royal Society of London. Series B, Biological Sciences* (1965), 295–309.

Magyari, Sümegi, et al. 2001
Enikő K. Magyari, Pál Sümegi, Mihály Braun, Gusztáv Jakab, and Mihály Molnár. "Retarded Wetland Succession: Anthropogenic and Climatic Signals in a Holocene Peat Bog Profile from North-east Hungary". *Journal of Ecology* 89.6 (2001), 1019–1032.

Magyari, Buczkó, Jakab, Braun, Szántó, et al. 2006
Enikő K. Magyari, Krisztina Buczkó, Gusztáv Jakab, Mihály Braun, Zsuzsa Szántó, Mihály Molnár, Zoltán Pál, and Dávid Karátson. "Holocene Palaeohydrology and Environmental History in the South Harghita Mountains, Romania". *Földtani Közlöny* 136.2 (2006), 249–284.

Magyari, Jakab, et al. 2008
Enikő K. Magyari, Gusztáv Jakab, Pál Sümegi, and Gy Szöőr. “Holocene Vegetation Dynamics in the Bereg Plain, NE Hungary – the Báb-tava Pollen and Plant Macrofossil Record”. *Acta Geographica Debrecina* 42 (2008), 1–16.

Magyari, Buczkó, Jakab, Braun, Pál, et al. 2009
Enikő K. Magyari, Krisztina Buczkó, Gusztáv Jakab, Mihály Braun, Zoltán Pál, Dávid Karátson, and István Pap. “Palaeolimnology of the Last Crater Lake in the Eastern Carpathian Mountains: A Multiproxy Study of Holocene Hydrological Changes”. *Hydrobiologia* 631.1 (2009), 29–63.

Magyari, Chapman, Passmore, et al. 2010
Enikö K. Magyari, John Chapman, D. G. Passmore, Judy R. M. Allen, Jacqui P. Huntley, and Brian Huntley. “Holocene Persistence of Wooded Steppe in the Great Hungarian Plain”. *Journal of Biogeography* 37.5 (2010), 915–935.

Magyari, Chapman, Fairbairn, et al. 2012
Enikő K. Magyari, John Chapman, Andrew S. Fairbairn, Mark Francis, and Margarita de Guzman. “Neolithic Human Impact on the Landscapes of North-East Hungary Inferred from Pollen and Settlement Records”. *Vegetation History and Archaeobotany* 21.4–5 (2012), 279–302. DOI: 10.1007/s00334-012-0350-6.

Mandaluniz, Ruiz, and Oregui 2009
N. Mandaluniz, R. Ruiz, and L. M. Oregui. “Habitat Use of Free and Mixed Livestock Ranging in Grassland-Heathland Mosaics of Atlantic Mountains”. *Options Méditerranéennes. Série A, Séminaires Méditerranéens* 85 (2009), 67–71.

Marinova et al. 2012
Elena Marinova, Spassimir Tonkov, Elissaveta Bozilova, and Ivan Vajsov. “Holocene Anthropogenic Landscapes in the Balkans: the Palaeobotanical Evidence from Southwestern Bulgaria”. *Vegetation History and Archaeobotany* 21.4-5 (2012), 413–427.

Medzihradszky 2001
Zsófia Medzihradszky. “The Holocene Sequence of the Pollen Record from Keszthely-Úsztatómajor, Hungary”. In *Annales historico-naturales Musei nationalis hungarici*. Vol. 93. 2001, 5–12.

Medzihradszky 2005
Zsófia Medzihradszky. “Holocene Vegetation History and Human Activity in the Kis-Balaton Area, Western Hungary”. *Studia Botanica Hungarica* 36 (2005), 77–100.

Meyers and Teranes 2001
Philip A. Meyers and Jane L. Teranes. “Sediment Organic Matter”. In *Tracking Environmental Change Using Lake Sediments*. Ed. by William M. Last and John P. Smol. Vol. 2: Physical and Geochemical Methods. Springer, 2001, 239–269.

Milchunas and Lauenroth 1993
Daniel G. Milchunas and William K. Lauenroth. “Quantitative Effects of Grazing on Vegetation and Soils over a Global Range of Environments”. *Ecological Monographs* 63.4 (1993), 327–366.

Notebaert and Verstraeten 2010
Bastiaan Notebaert and Gert Verstraeten. “Sensitivity of West and Central European

River Systems to Environmental Changes during the Holocene: A Review”. *Earth-Science Reviews* 103.3 (2010), 163–182.

Parsons 2011
Timothy A. Parsons. *Places, Pots, and Kurgans: Late Copper Age Patterns of Settlement and Material Culture on the Great Hungarian Plain*. Ph.D. Dissertation. Florida State University Tallahassee, 2011.

Payne 1973
Sebastian Payne. “Kill-off Patterns in Sheep and Goats: The Mandibles from Aşvan Kale”. *Anatolian Studies* 23 (1973), 281–303.

Putfarken et al. 2008
Dorothee Putfarken, Jürgen Dengler, Stephan Lehmann, and Werner Härdtle. “Site Use of Grazing Cattle and Sheep in a Large-Scale Pasture Landscape: A GPS/GIS Assessment”. *Applied Animal Behaviour Science* 111.1-2 (2008), 54–67. DOI: 10.1016/j.applanim.2007.05.012.

Reimer et al. 2013
Paula J. Reimer, Edouard Bard, Alex Bayliss, J. Warren Beck, Paul G. Blackwell, Christopher Bronk Ramsey, Caitlin E. Buck, Hai Cheng, R. Lawrence Edwards, and Michael Friedrich. “IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 years cal BP”. *Radiocarbon* 55.4 (2013), 1869–1887.

Risch, Krüsi, and Grämiger 2001
Anita C. Risch, Bertil O. Krüsi, and Helena Grämiger. “Spatially Specific Simulation of the Long-Term Development of a Subalpine Pasture in the Swiss National Park” (2001). DOI: 10.5169/seals-377836.

Rooijakkers 2012
C. Tineke Rooijakkers. “Spinning Animal Fibres at late Neolithic Tell Sabi Abyad, Syria?” *Paléorient* 38.1-2 (2012), 93–109.

Schumacher, Schier, and Schütt (in press)
Martin Schumacher, Wolfram Schier, and Brigitta Schütt. “Mid-Holocene Landscape Development and Herding-Related Vegetation Change in the Carpathian Region”. *Quaternary International*. DOI: http://dx.doi.org/10.1016/j.quaint.2015.09.074. In press.

Schütz et al. 2003
Martin Schütz, Anita C. Risch, Eliane Leuzinger, Bertil O. Krüsi, and Gérald Achermann. “Impact of Herbivory by Red Deer (Cervus elaphus L.) on Patterns and Processes in Subalpine Grasslands in the Swiss National Park”. *Forest Ecology and Management* 181.1 (2003), 177–188.

Sherratt 1981
Andrew Sherratt. “Plough and Pastoralism: Aspects of the Secondary Products Revolution”. In *Pattern of the Past*. Ed. by Ian Hodder, Glynn Isaac, and Norman Hammond. Cambridge: Cambrdge University Press, 1981, 261–306.

Sherratt 1982
Andrew Sherratt. “The Development of Neolithic and Copper Age Settlement in the

Great Hungarian Plain Part I: the Regional Setting". *Oxford Journal of Archaeology* 1.3 (1982), 287–316. DOI: 10.1111/j.1468-0092.1982.tb00315.x.

Sherratt 1983
Andrew Sherratt. "The Development of Neolithic and Copper Age Settlement in the Great Hungarian Plain Part II: Site Survey and Settlement Dynamics". *Oxford Journal of Archaeology* 2 (1983), 13–41. DOI: 10.1111/j.1468-0092.1983.tb00093.x.

Tanţău, Reille, de Beaulieu, et al. 2003
Ioan Tanţău, Maurice Reille, Jacques-Louis de Beaulieu, Sorina Fărcaş, Tomasz Goslar, and Martine Paterne. "Vegetation History in the Eastern Romanian Carpathians: Pollen Analysis of two Sequences from the Mohoş Crater". *Vegetation History and Archaeobotany* 12.2 (2003), 113–125.

Tanţău, Reille, Beaulieu, and Fărcaş 2006
Ioan Tanţău, Maurice Reille, Jacques-Louis de Beaulieu, and Sorina Fărcaş. "Late Glacial and Holocene Vegetation History in the Southern Part of Transylvania (Romania): Pollen Analysis of Two Sequences from Avrig". *Journal of Quaternary Science* 21.1 (2006), 49–61.

Tanţău, Reille, Beaulieu, Fărcaş, and Brewer 2009
Ioan Tanţău, Maurice Reille, Jacques-Louis de Beaulieu, Sorina Fărcaş, and Simon Brewer. "Holocene Vegetation History in Romanian Subcarpathians". *Quaternary Research* 72.2 (2009), 164–173.

Tanţău et al. 2011
Ioan Tanţău, Angelica Feurdean, Jacques-Louis de Beaulieu, Maurice Reille, and Sorina Fărcaş. "Holocene Vegetation History in the Upper Forest Belt of the Eastern Romanian Carpathians". *Palaeogeography, Palaeoclimatology, Palaeoecology* 309.3 (2011), 281–290.

Tanţău et al. 2014
Ioan Tanţău, Angelica Feurdean, Jacques-Louis de Beaulieu, Maurice Reille, and Sorina Fărcaş. "Vegetation Sensitivity to Climate Changes and Human Impact in the Harghita Mountains (Eastern Romanian Carpathians) over the Past 15 000 Years". *Journal of Quaternary Science* 29.2 (2014), 141–152.

The R Project
The R Project for Statistical Computing. *R: A Language and Environment for Statistical Computing*. http://www.R-project.org/.

Thünen 2014
Johann Heinrich von Thünen. *Der Isolierte Staat*. 1, Reprint of the Original from 1921. Paderborn, Germany: Salzwasser Verlag GmbH, 2014.

Verstraeten et al. 2009
Gert Verstraeten, Tom Rommens, Iris Peeters, Jean Poesen, Gerard Govers, and Andreas Lang. "A Temporarily Changing Holocene Sediment Budget for a Loess-Covered Catchment (Central Belgium)". *Geomorphology* 108.1 (2009), 24–34.

Vila and Helmer 2014
Emmanuelle Vila and Daniel Helmer. "The Expansion of Sheep Herding and the Development of Wool Production in the Ancient Near East". In *Wool Economy in*

the Ancient Near East and the Aegean. Ed. by Catherine Breniquet and Cécile Michel. Ancient Textile Series 17. Oxford: Oxford Books, 2014, 22–40. https://www.academia.edu/8794189/2._The_Expansion_of_Sheep_Herding_and_the_Development_of_Wool_Production_in_the_Ancient_Near_East_An_Archaeozoological_and_Iconographical_Approach (visited on 04/01/2016).

Waetzoldt 1972
Hartmut Waetzoldt. *Untersuchungen zur neusumerischen Textilindustrie*. Rom: Centro per le Anctichità e la Storia dell'Arte del Vicino Oriente, 1972.

Warren and Mysterud 1991
Jerry T. Warren and Ivar Mysterud. "Summer Habitat Use and Activity Patterns of Domestic Sheep on Coniferous Forest Range in Southern Norway". *Journal of Range Management* 1.44 (1991), 2–6.

Whitlock and Larsen 2001
Cathy Whitlock and Chris Larsen. "Charcoal as a Fire Proxy". In *Tracking Environmental Change Using Lake Sediments*. Ed. by John P. Smol, H. John B. Birks, and William M. Last. Vol. 3: Terrestrial, Algal and Silicious Indicators. Dordrecht, The Netherlands: Kluwer Academic Publishers, 2001, 75–97.

Willis 1997
Katherine J. Willis. "The Impact of Early Agriculture Upon the Hungarian Landscape". In *Landscapes in Flux – Central and Eastern Europe in Antiquity*. Ed. by John Chapman and P. Dolukhanov. Oxford: Oxbow Books, 1997, 193–207.

Willis, Braun, et al. 1997
Katherine J. Willis, Mihály Braun, Pál Sümegi, and Albert Tóth. "Does Soil Change Cause Vegetation Change or Vice Versa? A Temporal Perspective from Hungary". *Ecology* 78.3 (1997), 740–750.

Willis, Sümegi, et al. 1995
Katherine J. Willis, Pál Sümegi, Mihály Braun, and Albert Tóth. "The Late Quaternary Environmental History of Bátorliget, NE Hungary". *Palaeogeography, Palaeoclimatology, Palaeoecology* 118.1 (1995), 25–47.

Wilson 1989
A. Doug Wilson. "The Development of Systems of Assessing the Condition of Rangeland in Australia". In *Secondary Succession and the Evaluation of Rangeland Condition. Westview Press, Boulder, Colorado*. Ed. by William K. Lauenroth and William A. Laycock. Westview Special Studies in Agricultural Science and Policy. Boulder, Colorado, USA: Westview Press, 1989, 77–102.

Zeder 2008
Melinda A. Zeder. "Domestication and Early Agriculture in the Mediterranean Basin: Origins, Diffusion, and Impact". *Proceedings of the National Academy of Sciences* 105.33 (2008), 11597–11604.

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