# Bones and seeds: an integrated approach to understanding the spread of farming across the western Balkans

## Introduction

The western Balkans is a key area for understanding early farming in prehistoric Europe, as it encompasses, in close but distinct geographic spaces, the two main streams of diffusion of animal and plant domesticates across the continent. From c.6000 BC onwards, early farming diffuses on the one hand across an inland corridor corresponding to modern-day inland Croatia, Serbia, Romania and Hungary, which will lead to further extension along the Rhine-Danube axis; on the other hand, early farming diffuses westwards along the northern Mediterranean, encompassing the Adriatic basin. The spatial proximity of both streams of diffusion offers a unique opportunity to cast a comparative eye over some of the earliest forms of farming in Europe.

Earlier research into the spread of the Neolithic often resorted to the concept of a Neolithic ‘package’, intimately linking the introduction of pottery, domesticated plants and animals, as well as new forms of lithic technology. While the concept of a single monolithic ‘package’ has been often criticised as too rigid (e.g. Çilingiroğlu 2005; Conolly et al 2011; Thomas 2003), it is undeniable that several new technologies (e.g. pottery and domesticated plants and animals) and changes to existing technologies (i.e. lithics) indeed appear to be associated during the earlier stages of the Neolithic across Europe (e.g. Biagi & Starnini 2010). While numerous meta-analyses of either the archaeobotanical or zooarchaeological records have been undertaken for several parts of Europe over the past decade (e.g. Antolin et al. 2015; Colledge et al. 2005; Conolly et al. 2011; Coward et al. 2008; Gaastra & Vander Linden 2018; Manning et al 2013a; Orton et al. 2016) limited attention has been paid to the potential interplay between animal husbandry and agricultural practices during the earlier European Neolithic.

Existing research has stressed the non-linear interplay of cultural and environmental factors in shaping the variations observed in the archaeological record (Bogaard & Halstead 2015; Colledge et al. 2005, Gaastra & Vander Linden 2018; Manning et al 2013a, 2013b; Orton et al 2016). Another possibility, less often considered, is the potential mutual influence of stock-breeding and agriculture upon one another. As both of these represent new systems of food production it is necessary to consider them jointly when investigating the interplay of cultural and environmental factors. This paper aims at filling this gap by first evaluating possible co-variations between both archaeobotanical and zooarchaeological records, and then evaluating the impact of environmental and cultural factors preferences on either domesticated plants or animals on the entire *food production system*.

## Background to research

The existence of both aforementioned streams of neolithisation is indicated by the spatial and temporal distribution of 14C dates (Bocquet-Appel et al. 2009), and corresponds to distinct archaeological complexes, first and foremost defined on pottery typological basis. Inland, the Early Neolithic corresponds to the Starčevo-Körös-Criş complex (SKC hereafter), whilst Early Neolithic assemblages across the Adriatic are associated with the Impresso complex. From c. 5500 cal BC onwards, the Middle and Late Neolithic across both research areas is marked by increasing cultural differentiation, reflected in the occurrence of several spatially more restricted cultural entities, including the Sopot, Butmir and Vinča cultures inland, and the Danilo (and its regional variants), Hvar or Catignano cultures in the Adriatic.

Previous research into the spread of early farming in the western Balkans shows that these typological divisions are, to some extent, echoed in the zooarchaeological record. The latter shows marked differences between each stream of diffusion, as well as between chronological phases of the Neolithic sequence (e.g. Gaastra & Vander Linden 2018; Radović 2011; Orton 2012; Orton et al 2016). Identified trends include (a) the dominance of sheep and goats at coastal Mediterranean sites; (b) chronological progression towards a focus on the exploitation of cattle and pigs at sites of the inland Neolithic with parallel growth in the importance of hunting in some regions; and (c) a pattern of increasing diversity in animal production systems through time and space (e.g. Gaastra & Vander Linden 2018; Orton et al 2016).

Previous archaeobotanical research has seldom focused specifically upon the Balkans or on chronological developments in the use of plant foods during the Neolithic (but see Bogaard and Halstead 2015; Colledge and Conolly 2007; Halstead 1994; Krauss *et al*. 2017; Ivanova et al. 2018). Early Neolithic archaeobotanical records from SKC and Impresso sites have been incorporated into large-scale studies on the development of the 'crop package', as it was transported from the Near East along across Turkey and then along the Mediterranean  and into Europe (Colledge and Conolly 2007; Colledge *et al*. 2004, 2005; Coward *et al*. 2008). Overall, the westward progression of agriculture shows a reduction in the taxonomic diversity of crop packages. Explanations for this pattern have been sought in neutral drift (i.e. copying mistakes linked to the expansion process of a small original population), changing climatic and geographical conditions (i.e. reflecting adaptability of crops to new conditions), or cultural/human factors (i.e. explicit preferences for certain crops by early farming communities), but no consensus exists as to the main causal factors for this process (Bogaard and Halstead 2015; Colledge *et al*. 2005; Colledge and Conolly 2007; Conolly *et al*. 2008; Pérez-Losada & Fort 2011). Regional syntheses of crop packages across the maritime and continental routes of Neolithisation through the Balkans point to shared patterns (e.g. increased diversity during the later stages of the Neolithic, Filipović and Obradović 2013; Filipović 2014; Reed 2015, 2016; Fiorentino *et al*. 2013; Rottoli and Castiglioni 2009). It is however noteworthy that no systematic comparison has ever been conducted between different Balkan regions or streams of Neolithisation, in particular comparing different ecologies and cultural affinities.

Chronological frameworks have been given primacy in the analysis of Neolithic production systems – in general through comparisons of the Early Neolithic in multiple areas (at different absolute chronologies) or through the variation across and between regions at a specific point in time at different relative chronologies (Colledge and Conolly 2007; Colledge et al. 2004, 2005, Coward *et al*. 2008; Gaastra & Vander Linden 2018; Greenfield 2017; Manning 2013b; Orton et al 2016; Reed 2015). Previous research has shown the utility of combining these approaches to examine both the initial and settled phases (early and later) of the Neolithic and the changes observed within and between regions during both periods (e.g Gaastra & Vander Linden 2018; McClure & Podrug 2016; Orton et al. 2016). Comparisons of both early and later Neolithic settlements will therefore allow us to examine both the variation within the process of the initial dispersal as well as subsequent local adaptations within each region studied.

[Table 1]

## Methods

The present research area includes both the Adriatic basin, as well as the central and western Balkans and the Pannonian plain (Figure 1). Although ecological conditions have changed since the Early Holocene, the broad geographical determinants that define bioregions (such as altitude, latitude and mountain ranges) have not, suggesting that boundaries have remained broadly comparable. Therefore, sites under study here have been grouped according to these bioregional differences. The contemporary Adriatic basin presents an overall bi-partition in terms of vegetation zones with a Mediterranean bioregional zone along the eastern and south-western shores, and a Continental bioregional restricted to the central and northern parts of Adriatic Italy. Southern Italy (within the Mediterranean biogeographical zone) includes Apulia, Basilicata and Calabria. Sites of the inland Neolithic stream have been divided into Continental, Sub-Alpine and Pannonian bioregional zones (European Environment Agency 2016).

The zooarchaeological dataset includes a total of 181 phase-samples from 162 sites. The present meta-analysis was conducted following methodological lines outlined in previous meta-analyses by members of the same research group (Orton et al. 2016, Gaastra and Vander Linden 2018). Data are restricted to taxonomic abundance by Number of Identified Specimens (NISP), the most common unit of quantification in zooarchaeology, and one which is routinely and consistently reported across the research area. All identified mammals larger than a hedgehog are included in the analysis, whilst other taxonomic groups such as birds, fish or microfauna are excluded from the dataset due to lack of consistency in both their recovery and reporting. When determinable, numbers of shed deer antler were excluded from NISPs as these do not necessarily denote the hunting of individuals. A minimum NISP cut-off of 100 taxonomically identified macromammals was applied for each phase-sample. Only counts of specimens identifiable to species or genus were included in the analysis, thus excluding identifications to broader categories such as ‘small ruminant’ or ‘large mammal’. *Bos sp*. (indeterminate wild or domestic cattle) and *Sus sp*. (indeterminate wild or domestic pig) have been allocated pro rata based upon the proportions of domestic vs. wild cattle and pig in each assemblage. This method is not applicable to the taxonomic category of *Ovis/Capra* (sheep/goat) as difficulties in distinguishing between these species in zooarchaeological identification results in the majority of identifications belonging only to this combined group. All identified *Ovis aries* and *Capra hircus* specimens have therefore been subsumed here within the common taxonomic category *Ovis/Capra*.

The dataset of charred plant macro-remains (excluding charcoal) contains 141 phase-samples from 129 sites. Reports vary from detailed, sample by sample descriptions, to mere lists of taxa by site. Presence/absence data (ubiquity) by site/phase has been successfully used to explore spatio-temporal changes in the composition of plant macro-remain assemblages and is used here as the common means of quantification across the dataset (e.g. Hubbard 1975; Colledge et al. 2004, 2005; Coward et al. 2008). Sites from which only plant impressions are recorded are not included as these samples demonstrate a significant recovery bias against pulses and gathered fruits and nuts. Cereals used in pottery/daub production usually represent a very specific and narrow selection of the range of crops utilised (cf. Fuller et al. 2014: 199-205; McClatchie & Fuller 2014), and casts of other seeds, fruits and nuts are rarely recovered.

Table 2 lists all edible plant taxa included in this study. These include cereals (present as grains or chaff), pulses, flax and known edible seeds, fruits and nuts. Non-edible wild taxa and possible arable weeds are not included as the aim is not to compare how domesticates were managed/cultivated, but rather to explore the dichotomy between the use of wild and domestic edible taxa. For every site the summed ubiquity of taxa per category is used in the analyses (functional taxonomic categories - see below). In other words, a score of 1 is given to every species within a category and the totals from each category are used to represent a site. When species or varieties of cereals are not specified (e.g. *Hordeum vulgare sensu lato* or *Triticum durum/aestivum*) the category is only given a score of 1.

None of the sites contained only records of *Triticum sp*. (i.e. all sites with wheat had at least one defined species). Spelt (*T. spelta*) and rye (*Secale cereale*) were also present during the Neolithic but their status as individual crops remain to be determined (de Vareilles 2018). Rye is first found in the Middle/Late Neolithic, and has been identified from one site in Dalmatia (site 142), and seven sites inland (sites 16, 95, 98, 101, 106, 118 and 128). Low concentrations of spelt suggestive of its presence as a crop contaminant are noted for both phases of the Neolithic (de Vareilles 2018), although identifications made prior to the formal descriptions of the 'new' glume wheat should be verified (Jones et al. 2000; Kohler-Schneider 2003). Broomcorn millet seeds (*Panicum miliaceum*) have also been recovered from Neolithic contexts but are not included here, as its cultivation in Europe is unlikely to pre-date the Bronze Age (e.g. Filipović and Obradović 2013: 42-3; Reed 2015: 612; Stevens et al. 2016: 1545; Valamoti 2016). Seeds from Neolithic contexts have been dated to much later periods, highlighting the high propensity for these small, round seeds to move within soil profiles and the necessity to date them directly (Hunt et al. 2008; Motuzaite-Matuzeviciute et al. 2013). Records of *Lens sp*. and *Pisum sp*. were given a score of 1 when species were not specified, as they are more likely to reflect levels of preservation than the presence of wild forms. Lentil and pea are amongst the oldest domesticated legumes and have always been considered part of the original crop-package to have spread out of the Near East (Zohary et al. 2012: 77-86). None of the archaeobotanical reports notes the presence of wild lentils and peas as indeed the study region is likely to lie beyond the wild range of these species (Zohary et al. 2012: 78, 83).

[Table 2]

Multiple samples from a single site were entered separately by phase. When multiple samples were present within a single phase, these were amalgamated together into a single phase-sample entry in the dataset. As such, records of faunal and floral remains were simply assigned to a phase from a particular site, without further descriptions of contextual provenance, sample size or recovery technique (information often lacking from reports). Details of recovery vary from hand collection to fully wet-sieved/systematically floated. Hand collection of animal bone can lead to an under-representation of small elements as has been determined from experimental research (e.g. Payne 1972). Earlier comparisons of taxonomic abundance and diversity in Neolithic zooarchaeological samples from different sieving regimes have shown that these do not preclude reliable taxonomic comparisons, although more detailed statistical comparisons of the representation of individual taxa cannot be made with confidence due to indeterminacies of these differences in collection (Orton et al., 2016).

Both archaeobotanical and zooarchaeological datasets were analysed using a combination of statistical methods, all undertaken in R (R Development Core Team, 2008). Correspondence analysis was employed to compare combined variations in the representation of all taxa between regions and phases (R package ‘ca’; Nenadić and Greenacre, 2007). This multivariate statistical tool, increasingly used in archaeobotanical and zooarchaeological meta-analyses (e.g. Colledge et al. 2004, 2005; Manning et al., 2013a, 2013b, Orton et al., 2016; Smith 2017; Smith and Munro 2009) aims at illustrating in a graphical way the relationship between sets of categorical variables. The analysis provides a series of measures, or dimensions, which explain a decreasing percentage of the total variance of the studied population.

Both plant and animal databases were compared through correspondence analysis via comparisons of functional taxonomic categories (i.e. wild edible plants, pulses, large wild animals) rather than individual taxa. This allows comparisons of resource exploitation while normalizing weighting of datasets with taxa which have regionally unequal distributions (i.e. wild half-ass, *Equus hydruntinus* or olive, *Olea europea*) (Gaastra and Vander Linden 2018; Smith 2017).

[Figure 1]
[Table 3]

## Integrating zooarchaeological and archaeobotanical data

Archaeological assemblages of plant and animal remains are subject to different pathways of preservation and different biases which may alter the proportional representation of the original taxa. Archaeological assemblages of animal bones are by their nature the discarded refuse of human procurement activities. Smaller animals and the smaller bones from medium-sized animals may be missed during excavation if systematic sieving is not employed. This is particularly the case for categories of small taxa such as birds and fish (Payne 1972). Other numerous factors (e.g. differences in soil chemistry) can also limit the preservation potential of animal bone in archaeological contexts. Thus, some sites may contain very poorly preserved or no animal bone material despite systematic sieving. As animal bones of many species are large enough to be noticed during excavation, those found can be easily recovered either for the immediate study by a zooarchaeologist or curated for later analysis. While this has not always been the case, the recovery of animal bones has become largely routine in modern archaeological excavations.

Archaeological assemblages of charred plant remains (excluding charcoal) are most commonly produced when crop-processing products and by-products are burnt (cf. Hillman 1981, 1984; Jones 1984). Remains can also be preserved as consumptive refuse (e.g. charred nut shells and fruit pips in hearths) or through accidental charring. Different plants and different plant parts will 'survive' charring differentially; nutshells and seeds rich in starch or lignin will 'survive' better than oily seeds (e.g. Boardman and Jones 1990; Märkle and Rösch 2008, Wright 2003). Additionally, excavation and recovery techniques will contribute to further selective biases.

With the exception of caches of preserved plant remains or seed impressions upon ceramics and other materials (e.g. daub fragments), the majority of archaeological plant remains are recovered from soil/sediment samples. The small size of archaeobotanical remains significantly limits the likelihood that charred material will be detected through conventional excavation and are generally only recovered through flotation. As with animal bones, the size of the mesh used will determine which taxa and plant parts are recovered. Thus, sites not practising flotation or sieving for the recovery of plant remains rarely generate comparable archaeobotanical data. While flotation is increasingly included on archaeological sites it is still not a systematic recovery technique. Differences in the recovery techniques of animal and plant remains within and between sites make comparisons extremely difficult. As shown on Table 3, only a limited proportion of all sites contains data for both plant and animal remains. Some zooarchaeological data come from sites excavated without the practice of flotation and some archaeobotanical data come from sites for which zooarchaeological analysis has yet to be conducted or for which bone preservation was extremely poor.

Combining data from multiple zooarchaeological and archaeobotanical assemblages is also subject to issues of quantification. Zooarchaeological data used in this analysis are compared through the Number of Identified Specimens (NISP) as the most basic unit of quantification and the one which is most commonly reported. By contrast, the archaeobotanical data used here has been recorded in a number of different ways, making quantitative comparisons impossible between the majority of sites. Therefore, only the presence or absence (ubiquity) of individual plant taxa can be systematically included for each site in the dataset. These different systems of quantification, while necessary to ensure methodological rigour in the analysis of each component part of the food exploitation system, do not allow for the direct combination of archaeobotanical and zooarchaeological data in a single analysis. This analysis has opted for the less directly comparable, but more methodologically sound, strategy of making qualitative rather than quantitative comparisons (VanDerwarker & Peres 2010). Archaeobotanical and zooarchaeological data are analysed separately via correspondence analysis and the patterns expressed for each aspect of food exploitation are compared for each region and chronological period.

## Results

### *Early Neolithic (c.6000-5500 cal BC)*

Comparison between both inland and maritime streams of Neolithisation show significant overlap between Early Neolithic plant and animal samples from sites of both areas. As shown in Figure 2, this overlap is more strongly expressed for plant than animal assemblages. Both categories of information point to a low exploitation of wild resources in the coastal Impresso, compared with a greater diversity in the exploitation of wild resources within the SKC.

Further patterning emerges when sites are plotted by bioregions, especially for plant assemblages (Figure 3). Analysis of animal bone assemblages shows the same pattern between bioregions as between streams of Neolithisation. Mediterranean coastal Neolithic sites show a high reliance upon sheep and goats and low levels of wild exploitation, whilst inland sites in both continental and pannonian bioregions present a greater range of variation in the exploitation of domesticated (e.g. sheep and goats vs. cattle and pigs) and wild animals. Adriatic Early Neolithic sites suggest minor differences between the Dalmatian and Italian coasts of the Adriatic in animal exploitation.

There are limited differences in edible plant exploitation between both regions, especially as there is a lower presence of edible wild plants in Mediterranean sites and a greater exploitation of edible wild plants in SKC sites from the Pannonian bioregion. Both Impresso and SKC groups demonstrate a range of practices for the exploitation of pulses, with distinct preferences between streams (lentil in the Adriatic and pea inland). Sites from the continental bioregion demonstrate comparative diversity, with some emphasising domestic grains (similar to Impresso sites), pulses, edible wild plants or a balance between these.

[Figure 2: Early Neolithic bones and plants by stream]
[Figure 3: Early Neolithic bones and plants by bioregion]

*Later Neolithic (c.5500-4500 cal BC)*
The Later Neolithic in both Adriatic and inland areas is characterised by a multiplication of archaeological cultures, as well as a diversification of the settlement pattern, with sites observed in a wider range of landscapes and environments. Comparisons of archaeobotanical and zooarchaeological records were made between both streams and their component bioregions. Animal remains show an inverse pattern from that of the early Neolithic, with a higher degree of variation for coastal than for inland sites (Figure 4). Inland sites show a focus on the exploitation of cattle and pigs, with a range in levels of wild animal exploitation. Coastal sites present a wide spectrum of exploitation practices for both domestic and wild animals. Plant remains, by contrast, indicate a higher degree of overlap between coastal and inland streams of the Later Neolithic in comparison with the initial centuries of Neolithic settlement, with an overall marked increase in diversity.

When both categories of exploitation data are broken down by bioregion for sites along the Adriatic clear differences in exploitation practices are evident, not only between bioregions (Mediterranean vs. continental) but also between both Adriatic coasts within the Mediterranean bioregion (Figures 5 and 6). Patterns of both plant and animal exploitations are distinct for each group, though they do not always follow the same trends for both plant and animal resources. Sites within the Mediterranean bioregion overall continue to demonstrate a dominant exploitation of sheep and goats and low levels of hunting (Figure 5). Sites of the eastern Adriatic (i.e. Dalmatian) coast evidence a more extreme version of this pattern than those of the western Adriatic (i.e. Italian) coast, as was already the case during the Early Neolithic. Higher levels of wild animal exploitation are limited to a few cave sites of the Italian coast (sites 158, 162 and 177), although unfortunately no comparative plant data is available from cave sites in the same area. Cave sites from the eastern Adriatic coast display no differences in the exploitation of either animal or plant remains (sites 133 and 142) from that seen at open-air sites.

Sites within the continental bioregion of central and northern Italy show a wider range of animal exploitation practices more consistent with the pattern seen for inland sites – a greater focus on the exploitation of cattle and pigs and a wide range in levels of wild animal exploitation. Plant remains similarly show a divergence between sites of these groups. Within the grain crops exploited by coastal sites, barley is more common at sites within the Mediterranean bioregion on both Adriatic coasts, whereas einkorn wheat is more common at sites in the continental bioregion. Sites of the western Adriatic coast are fully divided between Mediterranean and continental bioregions, with far higher levels of wild plant exploitation at sites within the continental bioregion. However, these differences cannot be attributed exclusively to environmental differences, as sites within the Mediterranean bioregion demonstrate far higher levels of wild plant exploitation along the western Adriatic coast compared with those on the eastern coast (Figure 5).

[Figure 4: Later Neolithic fauna and plants by stream]
[Figure 5: Later Neolithic coastal stream fauna and plants by bioregion]
[Figure 6: Later Neolithic inland stream fauna and plants by bioregion]

Exploitation practices of the inland Neolithic show a far less discernible patterning according to bioregion. Sites from the continental and Pannonian bioregions cannot be differentiated as all demonstrate a similar husbandry regime primarily based on cattle, pig, cereals and pulses. There is a considerable range in the levels of wild exploitation across the inland sites. Sites in the continental bioregion are distributed in two distinct groups along a north-south gradient (Figure 6). There is no further patterning based either on elevation or immediate topography. Northern sites (sites 3, 5, 8, 10, 15, 16, 19, 21, 23, 27, 32, 33, 36, 40, 42, 46 and 47) within this gradient exhibit higher levels of wild plant exploitation and lower levels of wild animal exploitation when contrasted with sites in southern areas of the continental bioregion. Exceptions include sites in Macedonia (sites 25 and 35) and a single cave site (31), which extend Early Neolithic trends of focus on sheep and goat husbandry and limited use of wild resources. Unfortunately, no plant remains are available from these sites. The few sites of the sub-alpine bioregion – all belonging to the Butmir culture – show a narrow pattern of animal exploitation focused on the herding of cattle and pigs and very low levels of wild animal exploitation. This contrasts with higher levels of wild plant exploitation.

### *Questions of Scale: regions, cultures and preferences*

The range of variation seen for sites of the Later Neolithic suggests that other divisions could be of use. While bioregions demonstrate clear patterns for Adriatic sites, no clear pattern emerges for inland sites. As a result, we have additionally divided sites of both the continental and Pannonian bioregions according to their cultural assignation.

Vinča culture settlements stretch along the entire north-south gradient of the continental bioregion and extend into the Pannonian bioregion. Given the north-south gradient observed in exploitation practices for Later Neolithic sites of the continental bioregion, Vinča settlements of the Later Neolithic were isolated and compared according to their geographical distribution. As shown in Figure 7, this north-south gradient is evident for Vinča sites with, for instance, increasing exploitation of wild plants in more northerly sites. The pattern seen for animal exploitation in continental sites is not seen across the entirety of the Vinča culture. While there is an overall decrease in wild animal exploitation from south to north across sites in the continental bioregion, sites in the Pannonian bioregion (i.e. from the northern part of the Vinča culture) exhibit high levels of both wild plant and animal exploitation. A previous study, based on the northern and southern extremes of the Vinča culture, had suggested an overall north-south gradient of increasing reliance upon wild animal exploitation (Greenfield 2017:191). Our more detailed data contradict this hypothesis: exploitation practices between continental and Pannonian Vinča settlements differ for both aspects of the agro-pastoral system, with a correspondence in exploitation practices at the northern and southern margins of the cultural group and an inverse pattern in between.

[Figure 7: Animal and plant remains from Vinča culture sites by geographic distribution]
[Figure 8: Animal and plant remains from sites of the pannonian bioregion by culture]

As the Pannonian bioregion in the later stages of the Neolithic is represented by three different cultural groups (Middle/Late Neolithic Sopot and Vinča, and Linearbandkeramik (LBK) cultures), sites of this bioregion have been compared on the basis of their cultural assignations. These three cultural groups present markedly different food production systems (Figure 8). The LBK is the most diverse, but with an overall pattern of low wild exploitation. The Pannonian Vinča sites, as already stated, exhibit high levels of wild exploitation. By contrast, sites of the Sopot culture  present low levels of wild exploitation and a far greater exploitation of pulses than either of the other two cultural groups. This indicates that the differences seen in plant and animal exploitation at Vinča sites located within or adjacent to the Pannonian bioregion are not strictly a result of environmental adaptations, but are also shaped by cultural preferences. Specifically, all cultural groups located within the Pannonian bioregion show distinct patterns of plant and animal exploitation, confirming the importance of cultural preferences in structuring food production systems.

## Discussion

Comparisons of exploitation practices for the Neolithic of the western Balkans and adjacent regions show that common trends in exploitation can be seen for plants and animals, although these are not perfectly synchronized in all areas. Comparisons by streams of Neolithisation provide the least beneficial insights into food production systems of the Neolithic. Practices of food production are far more heavily influenced by bioregion and local cultural preferences than by their parent stream of Neolithic diffusion. While patterns in species preferences can be seen for exploited domesticates, such as preferences for ovicaprines vs. cattle and pigs, for barley vs. einkorn and for lentil vs. pea, the dominant divergences relate to the use of wild resources. While the increased exploitation of wild plants is most often paired with an increase in wild animals, this correlation is not systematic (e.g. sub-alpine sites of the Butmir culture, Vinča culture sites in the northern margins of the continental bioregion).

Patterns of plant and animal exploitation observed in the Early Neolithic do not translate onto those observed in the Later Neolithic within a given bioregion. Therefore, while comparisons of food production systems according to bioregions are of far greater utility than comparisons by stream of Neolithic diffusion, environmental conditions, as reflected by bioregions, do not solely drive variation in systems of food production. Differences in food production systems are observed between bioregions, as well as between sites of the same culture located in different bioregions (e.g. Vinča culture). However, equally important differences in food production systems also exist between sites of different cultures located within the same bioregion (e.g. Vinča, Sopot and LBK in the Pannonian bioregion). These combined regional and cultural patterns provide perhaps the best insight into the food provisioning trends exhibited in the Neolithic of the western Balkans and adjacent regions. Patterns of resource exploitation can be seen through these data to relate to both bioregional limitations and cultural preferences. While some taxa may be more suited to a particular bioregion and so more intensively exploited locally (e.g. sheep and goats or barley in the Mediterranean), the choices made by societies can be considered of equal importance in structuring patterns of food production.

## Conclusions

This study highlights the importance of considering food production systems as a whole and not simply examining separate patterns of plant or animal exploitation. The patterns identified from these data also demonstrate the importance of comparing cultural and regional patterns within the broader context of the spread of the Neolithic, as local preferences can strongly influence systems of food production. Given the regional, bioregional and cultural variation identified from this study, comparisons of production made between a limited number of sites from the same culture or bioregion may well miss important trends in food production identifiable through more detailed comparative meta-analysis.

The greater variation in food production practices identified between groups of sites in the later stages of the Neolithic serves to illustrate the importance of considering the Neolithic as a long-term process and not simply a wave of initial settlements spreading across Europe – the choices made in each region at the time of initial settlement should always be contrasted with later patterns after settlements and practices of food production have had time to embed and develop. This comparative assessment of Neolithic food production provides a more sound basis for understanding patterns and preferences in the exploitation of food resources, as choices made in the early centuries of the spread of farming demonstrate change (in some cases little, in others substantially) as settlements have adapted to local environments and societal preferences.

This study used an integrated assessment of zooarchaeological and archaeobotanical data to identify patterns of Neolithic food production. Due to differences in preservation, recovery and quantification between these areas of analysis, direct comparisons of proportional representation and/or contextual provenance are not feasible. Nevertheless, the integration of such different datasets through parallel analyses, using the same techniques and comparative frameworks, allows for a robust assessment of the combined food production systems. Future studies would benefit from a more integrated framework of analysis between zooarchaeology and archaeobotany, enabling more direct comparisons of the proportional representation of taxonomic categories. The datasets used here do not provide sufficient detail to address further relationships between the management of herds and the intensity of crop production. Until more direct and systematic integration can be achieved for a wider range of zooarchaeological and archaeobotanical data, more detailed analyses of integrated husbandry regimes will remain at the level of individual sites and analysts. Further combined studies of plant and animal remains – either using the techniques employed here or other quantitative tools – would greatly improve our understanding of prehistoric food production systems.

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