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Exploring Byzantine and Ottoman economic history with the use of palynological data: a quantitative approach*

With 1 map and 32 figures

Abstract: This paper discusses the results of a numerical analysis of the existing palynological evidence from medieval and early modern Balkans and Anatolia; as such, it hopes to provide new quantitative data for the study of Byzantine and Ottoman economic history. After presenting the palynological database prepared for this project – as well as the numerical methods developed specifically to deal with this material – the core of the paper is devoted to historical interpretation. In the first section we deal with the late antique and early medieval periods, demonstrating that signs of both late antique agrarian prosperity and early medieval economic collapse may be observed across Greece, Macedonia and Anatolia. The following section focuses on evidence for the development of a pastoral economy in the central Balkan mountain ranges, between the early Middle Ages and the Ottoman era. The third section discusses environmental aspects of the middle Byzantine economic revival. Finally, the paper focuses on how different regions of the Balkans and Anatolia fared during the late Byzantine and Ottoman periods; in particular, we demonstrate how the Byzantine economic system came to an end, and how a new economic geography emerged during the Ottoman era.

INTRODUCTION

The lack of quantitative data – data which might allow for reliable comparisons of economic performance on a national or regional level – is one of the greatest challenges faced by economic historians of pre-modern societies. The written record rarely provides numbers that are reliable and in long-enough series to make quantifications and numerical analyses possible.[1] Given the bad preservation of much Byzantine archival material (with the notable exception of the Athos documents), this limitation is felt very strongly by historians of Late Antiquity and Byzantium. Moreover, whereas there are increasing attempts to apply quantitative analyses (including GIS) in recent archaeological research,[2] they are generally restricted to sites or areas studied within the scheme of a particular project. Due to differences both in the methodologies of archaeological surface surveys and in the local contexts, long-term cross-regional comparisons using numerical tools have not yet been attempted on the archaeological data for Byzantium; and if such comparisons were attempted, they would

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1 With the obvious exception of papyrology. In the case of Byzantium, one notable exception are the Athos archives, as has been proven by the analyses of A. E. Laiou, Peasant Society in the Late Byzantine Empire. A Social and Demographical Study. Princeton 1977; J. Lefort, Analyse automatique des documents fiscaux byzantins. *Publications de l'École française de Rome* 31 (1977) 277–289 and P. Bellier *et alii*, Paysages de Macédoine: leurs caractères, leur évolution à travers les documents et les récits des voyageurs (*Travaux et Memoires, Monographies* 3). Paris 1986.

2 For instance, J. Crow – S. Turner, Silivri and the Thracian hinterland of Istanbul: an historic landscape. *Anatolian Studies* 59 (2009) 167–181; J. Bintliff, Central Greece in Late Antiquity: The Evidence from the Boeotia Project. *Late Antique Archaeology* 9 (2012) 189–203.

certainly involve considerable methodological challenges. The same numbers can have a different meaning depending on a site or region; consequently, the only possible approach is often to compare and synthesise, in a qualitative way, results that have already been interpreted in the context of individual projects. With this in mind, we hoped to overcome these problems by applying numerical procedures to data drawn from the field of environmental sciences. This paper presents both our approach[3] and the results we obtained, as well as new insights into Byzantine and Ottoman economic history that arose from our analysis.

The problem of incompatibility, especially with regard to datasets from different textual sources or archaeological projects, does not apply to palynological evidence. Palynologists extract and process data following a rigorous methodology; the procedures used by researchers – who take sediment cores from lakes and marshes which contain pollen grains deposited during the previous millennia – are virtually identical from site to site. In each sample taken from a core, the pollen grains are identified as belonging to a particular plant taxon (a species or a group of species) in the course of standardised laboratory analyses. In this way, every sample provides information on the pollen signal produced by the landscape that existed around a specific site at the time when a particular layer of sediment was accumulating. Consequently, the changing percentage values of various taxa (obtained by dividing a taxon's pollen count by the sample's pollen sum within a particular sample[4]) serve as a basis for reconstructing local vegetation histories.[5] Such datasets usually span much longer time periods than anything we could obtain from texts or archaeological material (they cover at least two-three millennia, often much more). As a result, palynology is able to provide continuous records of vegetation changes at a given location during both the Byzantine and Ottoman periods. Historians have already started to integrate these local vegetation reconstructions into a larger vision of late antique and Byzantine socio-economic history.[6] However, no attempt has yet been made to exploit the fact that palynological data constitutes a huge amount of quantitative information on substantial parts of the Byzantine world. Consequently, the aim of our project was to obtain quantitative reconstructions of landscape and vegetation transformations at a regional level that would integrate palynological information from several individual sites and that would allow reliable cross-regional comparisons. Since in both Greece and Anatolia man was already capable of bringing about major transformations

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[3] Discussed in detail in a separate methodological article: A. Izdebski – G. Koloch – T. Słoczyński – M. Tycner, On the Use of Palynological Data in Economic History: New Methods and an Application to Agricultural Output in Central Europe, 0–2000 AD. *Exploration in Economic History* 59 (2016) 17–39.

[4] The pollen sum is never constant even within the same core, i.e. the same pollen site dataset; usually it ranges from two hundred to more than one thousand grains, depending on a counting strategy of an analyst and the quality of material in each sample.

[5] In this case, "local" means different things depending on which pollen-producing plant we think of: e.g., vine pollen does not normally travel farther than 2 km, while olive pollen can travel more than 100 km. In simple terms, a core can be considered to represent the radius of 2–5 km, depending on local topography, and at the same time to contain some regional signal for trees like olive or pine. For useful introductions to palynology, see W. J. Eastwood, Palaeoecology and eastern Mediterranean landscapes: Theoretical and practical approaches, in: General issues in the study of medieval logistics: sources, problems, and methodologies, ed. J. F. Haldon (*History of Warfare 36*). Leiden 2006, 119–158, and the introductory chapters in M. Vermoere, Holocene Vegetation Dynamics in the Territory of Sagalassos (Southwest Turkey). A Palynological Approach. Turnhout 2004 and A. Izdebski, A rural economy in transition. Asia Minor from Late Antiquity into the Early Middle Ages (*Journal of Juristic Papyrology*, *Supplement Series* 18). Warsaw 2013.

[6] J. Haldon, "Cappadocia will be given over to ruin and become a desert". Environmental evidence for historically-attested events in the 7th–10th centuries, in: Byzantina Mediterranea, ed. K. Belke *et alii*. Wien 2007, 215–230; F. L. Cheyette, The disappearance of the ancient landscape and the climatic anomaly of the early Middle Ages: a question to be pursued. *Early Medieval Europe* 16 (2008/2) 127–165; M. Whittow, The Middle Byzantine Economy (600–1204), in: The Cambridge history of the Byzantine Empire c. 500–1492, ed. J. Shepard. Cambridge 2008, 465–492; A. Izdebski, Why did agriculture flourish in the late antique East? The role of climate fluctuations in the development and contraction of agriculture in Asia Minor and the Middle East from the 4th till the 7th c. AD. *Mill* 8 (2011) 291–312; Izdebski, A rural economy in transition 107–215.

in the natural environment by the first millennium BC [7], from this point onward the history of vegetation can be interpreted more or less as a direct reflection of socio-economic change. Therefore, the reconstructions presented in this paper offer new insights into the regional economic histories, as our results provide quantitative representations of a society's impact on its regional landscape.

DATABASE

The main challenge we faced while creating our database was assuring as high a chronological resolution as possible while, at the same time, achieving reasonable certainty regarding the chronology of socio-economic change. This meant that we had to pay special attention to certain chronological issues even prior to conducting our analyses when we were building our database of Byzantine-Ottoman palynological data.

Apart from very rare situations, where annually-deposited layers of sediment are recognisable and can simply be counted,[8] sediment cores containing pollen require radiocarbon dating and mathematical modelling of the relation between core depth and calendar years (age-depth modelling). In most cases, dozens of samples are taken from a single core, making it practically impossible to have ^{14}C dates for all of them. However, this is not the only problem. Even if we radiocarbon-dated every sample from a core, each radiocarbon date still has its confidence intervals – that is, a margin of uncertainty involved in assigning a specific year to the analysed sample of organic material – and the relationship between the radiocarbon and calendar age is not linear. This is why radiocarbon dates need mathematical processing and calibration in order to provide an estimated calendar age for each sample that has been taken from a core.

Consequently, from all the palynological sites in the Eastern Mediterranean (including the Balkans) available in the European Pollen Database as of 18 April 2014, or published in scientific journals,[9] we could use only those which have at least one radiocarbon date for the last three and a half millennia (preferably more) as well as a relatively certain dating of the core surface. We then had to make sure that, for each site, the age-depth model we included in our database was the most reliable model available. Since several of our sites were studied several decades ago – and approaches to age-depth modelling have improved considerably in recent years – we decided to construct our own models for around two-thirds of the sites (we also produced new models for recently published sites that have not been provided with estimated ages for every sample). For this purpose, we employed the latest version of the modelling software called *clam* (designed by M. Blaauw) which, in turn, uses the most recent radiocarbon calibration curve.[10]

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[7] For an overview, see J. D. Hughes, Pan's travail: environmental problems of the ancient Greeks and Romans. Baltimore 1993. An Anatolian example is discussed in W. J. Eastwood – N. Roberts – H. F. Lamb, Palaeoecological and Archaeological Evidence for Human Occupance in Southwest Turkey: The Beyşehir Occupation Phase. *Anatolian Studies* 48 (1998) 69–86. Finally, J. Bakker and others offer an interesting discussion of anthropogenic and "post-anthropogenic" phases in vegetation history of South-Western Anatolia: J. Bekker *et alii*, Man, vegetation and climate during the Holocene in the Territory of Sagalassos, Western Taurus mountains, SW Turkey. *Vegetation History and Archaeobotany* 21 (2012) 249–266.

[8] There are only two sites with this type of data in the entire Balkans and Anatolia – Lake Nar in Cappadocia and Lake Butrint in Albania, see A. England *et alii*, Historical landscape change in Cappadocia (central Turkey): a palaeoecological investigation of annually-laminated sediments from Nar lake. *The Holocene* 18 (2008) 1229–1245; D. Ariztegui *et alii*, Natural and human-induced environmental change in southern Albania for the last 300 years – Constraints from the Lake Butrint sedimentary record. *Global and Planetary Change* 71 (2010) 183–192.

[9] Their raw data were made available to us by original investigators, for which we are very grateful. Please see acknowledgements for more information. On the European Pollen Database, see R. Fyfe *et alii*, The European Pollen Database: past efforts and current activities. *Vegetation History and Archaeobotany* 18 (2009) 417–424; access: http://www.europeanpollendatabase.net (18.04.2014).

[10] M. Blaauw, Methods and code for "classical" age-modelling of radiocarbon sequences. *Quaternary Geochronology* 5 (2010) 512–518; P. J. Reimer *et alii*, IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon* 51 (2009) 1111–1150.

Table 1 gives essential information on each core together with a reference to the original publication and the age-depth model included in our database. The new age-depth models for Anatolian sites have already been published elsewhere, whereas the new models for the Balkan sites are presented in Table 2. Table 1 also provides information on the chronological quality of each site. Since the number of radiocarbon dates differs considerably from one core to another, we decided to include this information in our database and take account of it in our analyses. Our sites are thus divided into three categories:

(1) sites with at least two radiocarbon dates for the entire core, of which at least one falls into the last two millennia (after 1 AD = 1950 cal BP[11]); the second date is not substantially (max. 20 years) older than 1000 BC = 3050 cal BP
(2) sites with at least one radiocarbon date for the entire core, not older than 500 BC = 2450 cal BP; dates older than this date are substantially older than 1000 BC = 3050 cal BP (more than 200 years)
(3) sites with at least one radiocarbon date from the last three and a half millennia.

Apart from providing information on the type of the age-depth model selected for each site, Table 2 contains information on the surface dates used in computations, as well as additional remarks on the radiocarbon dates used in a model, wherever necessary. In the case of all sites, radiocarbon dates have been taken from original publications, after a cross-check with the European Pollen Database and Pangaea (another online database of environmental data).

Table 1. Palynological sites from Anatolia and the Balkans. For full references see Appendix 1.

	Site name	Latitude	Longitude	Chron. quality	Original publication	Age-depth model
				Anatolia		
1	Ova	36.266	29.300	2	Bottema & Woldring 1984	Izdebski 2013
2	Köyceğiz	36.875	28.642	1	van Zeist et al. 1975	Izdebski 2013
3	Söğüt	37.050	29.883	3	van Zeist et al. 1975	Izdebski 2013
4	Gölhisar	37.133	29.600	1	Eastwood et al. 1999	Eastwood et al. 2007
5	Pinarbaşı	37.466	30.050	2	Bottema & Woldring 1984	Izdebski 2013
6	Bereket 1	37.545	30.295	2	Kaniewski et al. 2007	Kaniewski et al. 2007
7	Bereket 2	37.545	30.295	1	Bakker et al. 2012	Bakker et al. 2012
8	Gravgaz	37.584	30.404	1	Bakker et al. 2012	Bakker et al. 2012
9	Beyşehir Gölü I	37.542	31.500	3	van Zeist et al. 1975	Izdebski 2013
10	Hoyran	38.275	30.875	1	van Zeist et al. 1975	Izdebski 2013
11	Küçük Akgöl	40.866	30.433	1	Bottema et al. 1993/1994	Izdebski 2013
12	Melen	40.766	31.050	3	Bottema et al. 1993/1994	Izdebski 2012
13	Abant	40.600	31.283	1	Bottema et al. 1993/1994	Izdebski 2012
14	Ladik	40.916	36.016	3	Bottema et al. 1993/1994	Izdebski 2012
15	Kaz	40.283	36.150	2	Bottema et al. 1993/1994	Izdebski 2012
16	Demiryurt	39.733	37.383	2	Bottema et al. 1993/1994	Izdebski 2012
				Balkans		
17	Lerna	37.500	22.583	2	Jahns 1993	New model – see Table 2
18	Vravron	37.920	24.000	1	Kouli 2012	Kouli 2012
19	Voulkaria	38.866	20.833	1	Jahns 2005	New model – see Table 2
20	Halos	39.166	22.833	1	Bottema 1974	New model – see Table 2

[11] Cal BP means calibrated (= calendar) years before present (= 1950 AD), as opposed to C14 BP, which is used for primary, uncalibrated results of radiocarbon age measurement.

	Site name	Latitude	Longitude	Chron. quality	Original publication	Age-depth model
21	Litochoro	40.138	22.546	3	Athanasiadis 1975	EPD cal BP model by S. Panajiotidis
22	Flambouro	40.259	22.171	1	Gerasimidis & Athanasiadis 1995	Gerasimidis & Panajiotidis 2010
23	Orestias	40.500	21.250	2	Kouli & Dermitzakis 2010	Kouli & Dermitzakis 2010
24	Khimaditis Ib	40.616	21.583	2	Bottema 1974	New model – see Table 2
25	Mount Voras	41.020	21.910	2	Gerasimidis & Athanasiadis 1995	Gerasimidis et al. 2009
26	Mount Paiko	41.052	22.275	1	Gerasimidis & Athanasiadis 1995	Gerasimidis et al. 2008
27	Lailias	41.266	23.600	1	Gerasimidis & Athanasiadis 1995	Gerasimidis & Athanasiadis 1995
28	Popovo Ezero	41.716	23.666	1	Stefanova & Bozilova 1995	New model – see Table 2
29	Elatia-Rhodopes	41.479	24.326	1	Gerasimidis & Athanasiadis 1995	EPD cal BP model by S. Panajiotidis
30	Besbog	41.750	23.666	2	Stefanova & Bozilova 1995	New model – see Table 2
31	Beliya Kanton	41.733	24.133	1	Lazarova et al. 2011	Lazarova et al. 2011
32	Begbunar	42.150	22.550	1	Lazarova et al. 2009	Lazarova et al. 2009
33	Sredna Gora Mountains Peat Bog	42.833	24.833	1	Petrov & Filipovitch 1987	New model – see Table 2
34	Straldza mire	42.633	26.783	1	Tonkov et al. 2009	Tonkov et al. 2009
35	Arkutino Lake 2	42.366	27.733	1	Bozilova & Beug 1992	New model – see Table 2
36	Lake Shabla-Ezeretz	43.583	28.550	1	Filipova-Marinova 1995	New model – see Table 2
37	Duranunlak 2	43.666	28.550	2	Bozilova & Tonkov 1985	New model – see Table 2
38	Mire Garvan	44.116	26.950	2	Lazarova 1995	New model – see Table 2

Table 2. New age-depth models.

Site name	Type of the model	Surface date	Additional remarks
Arkutino Lake 2	cubic spline	Not used in modelling (no information)	Cubic spline selected in order to avoid problems with the surface date; based on the two youngest ^{14}C dates.
Besbog	polynomial regression (3)	0 cm assumed as 0 cal BP	Highly credible, regular accumulation rate (also in a cubic spline model); the third ^{14}C date (VRI–968) not used in modelling.
Duranunlak 2	linear interpolation	0 cm assumed as 0 cal BP	Linear regression is the only solution due to age reversals occurring in other models; outliers suggested in the original publication were removed from modelling.
Halos	polynomial regression (3)	0 cm assumed as 0 cal BP	The oldest ^{14}C date was not used in the computations because of its age.
Khimaditis Ib	linear interpolation	0 cm assumed as 0 cal BP	Very strong acceleration of accumulation rate in the last two millennia; no obvious outliers.
Lake Shabla-Ezeretz	linear interpolation	0 cm assumed as 0 cal BP	Highly credible, regular accumulation rate.
Lerna	smoothing spline (0.37)	0 cm assumed as –30 cal BP	The investigator warns against putting too much certainty in the ^{14}C dates, probability of reservoir effects is high. Therefore, qualified as the 2nd category in terms of chronological quality.
Mire Garvan	linear interpolation	0 cm assumed as 0 cal BP	
Popovo Ezero	cubic spline	0 cm assumed as 0 cal BP	Highly credible, regular accumulation rate.
Sredna Gora Mountains Peat Bog	cubic spline	0 cm assumed as 0 cal BP	The assumption for surface date is an informed guess; the two contradictory dates for 155 cm were excluded from modelling.
Voulkaria	cubic spline	Not used in modelling	Dates identified as erroneous or problematic by the investigator were excluded from modelling.

In every palynological study, grains of all pollen-producing plants are counted. The process of counting and identifying grains in a sample continues until it reaches a certain level, most often a certain total sum of pollen grains (for instance, an analyst can aim at having the average pollen sum of 1000 grains). As a result, all elements of local vegetation that produce pollen are represented in the site data, both those that are influenced by human activity and those that remain unaffected. Since the focus of our project is the economic activity reflected in landscape transformations, we did not include all plant taxa in our database and analyses. Instead, we limited our attention to cultivated plants, secondary anthropogenic indicators (uncultivated plants related to human activity, such as common weeds of cereal fields, plants favoured by pastoralism, etc.), steppic vegetation, and key forest trees. However, pollen sums we used were based on all the taxa identified in a given sample (trees, herbs, and shrubs). In some cases, these sums were adjusted in a way that was suggested by the site's investigator in the original publication (for instance, in some cases we excluded true grasses from the sum, as they represented only the local marsh vegetation).

It should be noted that the geographical coverage of our database is limited by the availability of pollen data. Due to a variety of natural and historical circumstances, there are countries and regions in the Eastern Mediterranean that are much better studied in terms of palynology, while there are also areas from which we have almost no data, or at least no data for the last three millennia. Thus, from the entire Balkan region, useful data is available only for Bulgaria and Greece and, consequently, only these two countries are represented in our database. Due to hydrological factors, lakes and marshes with proper sediment deposits do not exist everywhere in the Levant; as a result, we have data only from isolated sites which do not necessarily cluster into coherent historical regions (a potential exception is modern Israel). Once we move to the Caucasus, there are plenty of palynological sites from Georgia, but hardly any are useful for the study of historical eras; sites from other countries are unfortunately very few. Finally, Turkey is relatively well covered by palynological research, though it is concentrated in two regions: the North and the South-West. Elsewhere, there are some isolated sites, but – again – they are too few and too dispersed to form a coherent region. This applies to the excellent site of Lake Nar,[12] the only site in entire south-eastern Anatolia whose chronology is reliable enough for historical analyses. Location of the sites, as well as the boundaries of regions chosen for the purpose of our analyses, are presented on Map 1, while the regions themselves are presented in Table 3.

Region A consists of four sites from different coastal areas of Central Greece (as these sites represent changes on the coasts, the observed trends cannot be assumed to reflect directly conditions in the Peloponnese or mainland Greece).

Region B represents the highland hinterlands of the Macedonian plain, with the majority of sites located to the west of the plain; it is important to bear in mind that the region contains no site from within the plain itself.

The sites that comprise **Region C** are located in the mountains of Western Bulgaria, primarily in the Rhodopes; here it is important to note that the sites are all located at relatively high altitudes, and may not reflect directly the vegetation changes taking place in the valleys.

In the course of our analyses, we also considered another region in this part of the Balkans – the Pirin Mountains (sites 27–31) – but its vegetation history proved very similar to the reconstructions we obtained for the whole of Western Bulgaria (the current Region C); this suggests that, in the medieval and early modern periods, the highlands of the Rhodopes (including the Pirin Mountains) and the western part of the Stara Planina had a common regional history in terms of the environment and economy.

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[12] England *et alii*, Historical landscape change in Cappadocia. On the historical significance of this data, see Haldon, Cappadocia will be given over to ruin and become a desert.

Region D consists of sites in Eastern Bulgaria, but unfortunately is not entirely coherent from an historical point of view. The parts of present-day Bulgaria located to the north and south of the Stara Planina constituted different regions in both Antiquity and the Middle Ages.

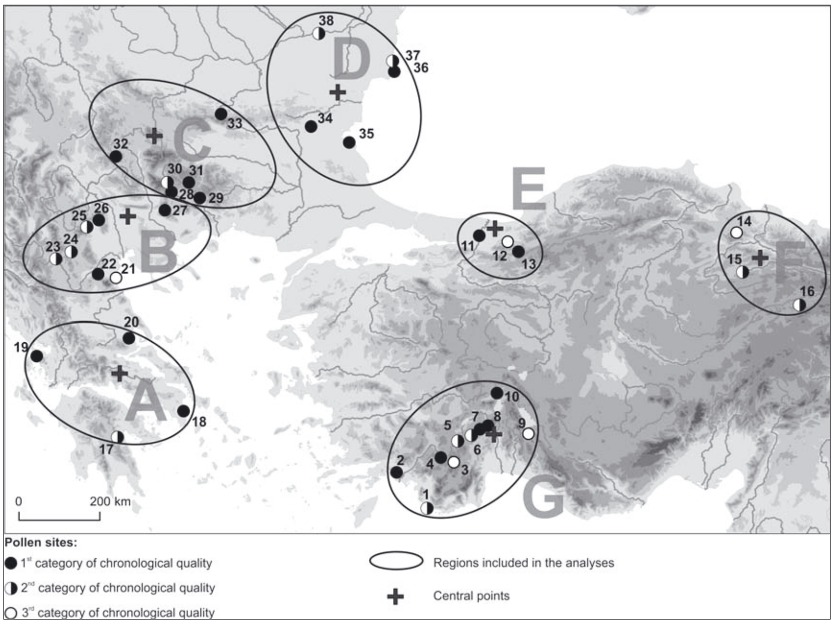
As we move to Anatolia, **Regions E and F** represent eastern Bithynia (different to that part of Bithynia that lies on the Marmara coast) and the inland part of the Roman province of Pontus (and not the Pontic coast of the Black Sea).

Finally, sites in South-Western Anatolia (**Region G**) are clustered around Pisidia and represent primarily this historical region. Some of the Region G sites, however, are located outside of this area – in Lycia or Karia – and our reconstructions may thus be considered representative at least for the inland parts of Lycia and eastern Karia.

Table 3. Regions.

	Region	Pollen sites included in computations (numbers and names)	Number of samples*	Central point
A	Central Greece	17–20: Lerna, Vravron, Voulkaria, Halos	98	38.5375 22.6275
B	Macedonia	21–27: Litochoro, Flambouro, Orestias, Khimaditis Ib, Mount Voras, Mount Paiko, Lailias	151	41.0475 22.9975
C	Western Bulgaria	28–33: Popovo Ezero, Elatia-Rhodopes, Besbog, Beliya Kanton, Begbunar, Sredna Gora Mountains Peat Bog	76	42.495 23.4275
D	Eastern Bulgaria	34–38: Straldza mire, Arkutino Lake 2, Lake Shabla-Ezeretz, Duranunlak 2, Mire Garvan	62	43.135 27.155
E	Eastern Bithynia	11–13: Küçük Akgöl, Melen, Abant	75	40.9875 30.735
F	Inland Pontus	14–16: Ladik, Kaz, Demiryurt	68	40.445 36.49
G	South-Western Anatolia	1–10: Ova, Köyceğiz, Söğüt, Gölhisar, Pinarbaşı, Bereket 1, Bereket 2, Gravgaz, Beyşehir Gölü I, Hoyran	368	37.565 30.6025

* Number of samples applies to the period of 501 BC–AD 2000.



Map 1. Sites and regions.

METHOD AND RESULTS

Our method – presented in detail in a separate methodological paper[13] – consists of three steps: interpolation, smoothing, and aggregation. In the first step, we correct a problematic feature of our initial data sets, the fact that there are time periods (years) for which no pollen samples were taken. Moreover, the time periods of these initial observations do not need to overlap across pollen sites, and they indeed rarely do. Therefore, we use a linear spline function to provide interpolated measurements for those time periods for which no actual samples were taken. This method of interpolation is most accurate given the fragmentary nature of our data, as individual linear interpolations are made separately between each pair of observations (i.e., core samples with pollen data). Without interpolating the missing observations for each calendar year, no further numerical analysis would be possible.

In the second step, we acknowledge that our data on the fractions of various pollen types is subject to error. This error might be either purely random in nature (e.g., environmental catastrophes, local anthropogenic events – with no regional significance) or it may also be related to inaccuracies in laboratory measurement. We therefore smooth our data using the Hodrick–Prescott filter which is designed to remove high-frequency fluctuations from time series. If any fractions become negative after such a smoothing, we replace them with zero. In this way our data becomes suitable for regional aggregation.

In the third step, we aggregate our data into regional trends. For each region, we define a central point; these points, in turn, define our regions of interest in the analysis. We then attempt to recover counterfactual trends in fractions of various pollen types at the locations that have been chosen to represent central points of each region. These trends are computed as weighted averages of site-specific trends where sites are restricted to those located in this given region and weights are determined endogenously by the structure of our data.

Specifically, we define two types of distance between a given site and our geographical location of interest (for instance, the central point of a selected region): spatial distance and time distance. The former is simply the Euclidean distance between these two locations. The latter, on the other hand, is the number of years between a given time period and the closest time period for which a measurement is available at a given site in the original data set. The spatial distance between two locations is therefore constant over time, while the time distance is not. For both types of distance, we assign greater weight to pollen sites which are closer to a given location, but we allow the degree of 'punishment' for large distances to vary endogenously. More specifically, we use cross validation in which we remove, one by one, pollen sites from our data set, and use our model to predict various pollen fractions at this site, using all the information which is available from other sites. We then compute the root-mean-square error of prediction which measures average differences between predicted fractions and actual fractions. We choose a structure of penalties for spatial distance and time distance that minimizes this error of prediction.

Finally, in order to check the spatial coherence of our regions, we have also conducted similar computations for four locations from the edges of a given region. In all cases, the trends on the edges did not differ substantially from the trends reconstructed for the central point. This means that a common (regional) trend may be found in the pollen data from all sites within a given region, and that our method is capable of recovering this trend. In other words, our regions share a common vegetation history and their boundaries are not just arbitrary and artificial creations.

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13 Izdebski – Koloch – Słoczyński – Tycner, On the Use of Palynological Data in Economic History.

In the end, we were able to obtain reconstructions of trends in the proportions of a wide variety of plant taxa within the total pollen signal from a given region. Figures presenting these results from AD 300 until the modern era are presented in Appendix 2 (smoothed for easier interpretation: Figures present moving averages of original results). These figures do not include any information about the scale of the vertical axes. In this way, we want to avoid confusion, since our data cannot be interpreted in absolute terms. One can only consider each figure individually for the relative changes between subsequent time periods. Each region is represented by four or five figures that present the cultivated taxa that are best represented in a given region as well as the structure of secondary anthropogenic indicators (common weeds), steppic vegetation, and forests.

HISTORICAL INTERPRETATION

Before engaging in historical interpretation of our results, it is first necessary to discuss their limitations. As it turned out in the course of our project, the availability of palynological data for the Balkans and Anatolia is much worse than for Central Europe, which formed another geographical focus of our project. In Central Europe, sites with reliable chronology are more numerous and they are clustered in a more coherent way. Consequently, the overall chronological reliability of the database is much higher, and the interpretation of results is far more straightforward.[14]

In theory, it should be possible to draw conclusions from every change, and especially every reversal, in the direction of a curve reflecting environmental and economic significance of specific plants or their groups. Moreover, the relative rate of growth or decline should also be meaningful. However due to the unsatisfactory quality of the Balkan-Anatolian database, it is not possible to interpret some of the phenomena that appear on our figures. One should bear in mind that a regional curve can be very strongly influenced by a single site whose trends are different compared to others in the same region (due to its good chronological quality, or differences in temporal resolution between sites, or the huge scale of the local vegetation change). In the following section, we will make the reader aware of any instances where such an issue has bearing on the interpretation. This phenomenon can also be applied to a group of sites within a region; South-Western Anatolia, for instance, is dominated by sites located in Pisidia, which provide 317 of the total 365 samples that build up this region's dataset. Nevertheless, this region remains the most reliable in our database; it is an absolute exception both in the number and distribution of its sites, as well as in the total number of sediment samples with the pollen data (technically, observations) available from the sites in this region.

The two other regions that provide relatively reliable information, on the grounds of the total number of pollen samples, are Macedonia (151 sites) and Central Greece (98 sites; for other regions see Table 3). In these cases, however, the total numbers of pollen samples are still below the average Central European level. Moreover, unlike in South-Western Anatolia – where the distribution of pollen samples per century is relatively even after AD 300 – in the case of these regions we observe notable irregularities. Whereas more recent centuries are better represented in the data for Macedonia, in the case of Greece the number of pollen samples per century – in other words, the information density – drops considerably after around AD 1000 (see Figure 1 and Figure 2). All other regions consist only of 60–70 samples – which calls for a cautious interpretation.

[14] Izdebski – Koloch – Słoczyński – Tycner, On the Use of Palynological Data in Economic History; A. Izdebski – G. Koloch – T. Słoczyński – M. Tycner, Historia Polski w świetle badań przyrodniczych. Analiza ilościowa danych palinologicznych. *Historyka. Studia Metodologiczne* 45 (2015) 127–160.

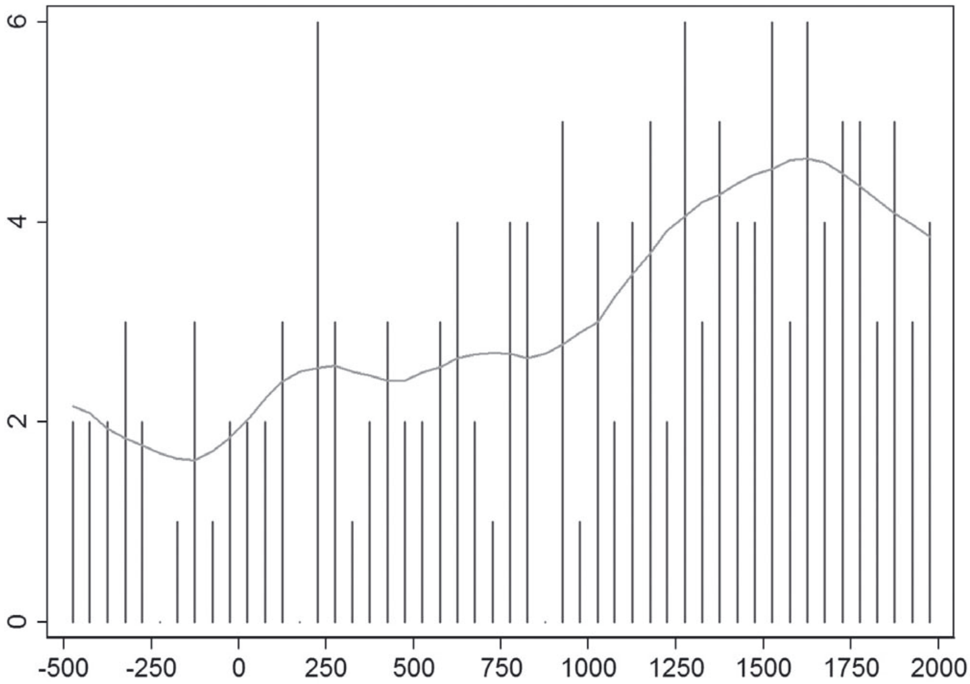

Figure 1. Number of pollen samples per 50 years in the palynological data from Macedonia.

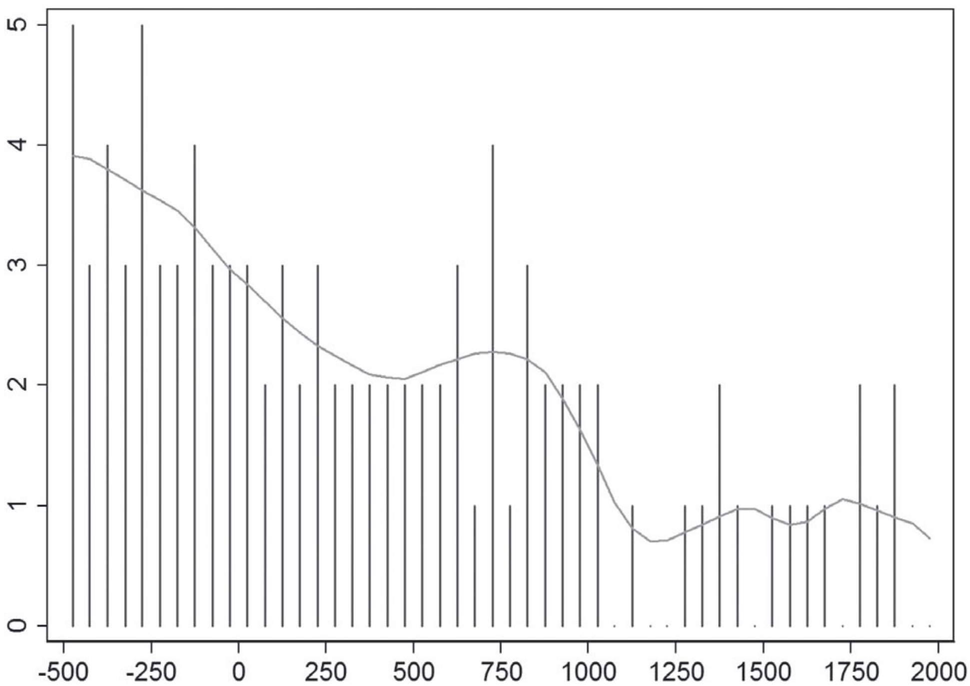

Figure 2. Number of pollen samples per 50 years in the palynological data from Central Greece.

Consequently, in the following interpretation – which is arranged according to historical periods and key issues in Byzantine economic history – not every change in every figure is going to be discussed. Rather, we are seeking to identify signs of major economic processes and substantial changes in agrarian output. It is worth noting that the quantitative analysis of pollen data presented here complements the picture that can be obtained from a qualitative analysis of the same palynological evidence, at least in the case of Anatolia. Moreover, it became clear that, even when regional data was relatively poor, there was still considerable potential for gathering significant historical information by looking at each site individually and interpreting the local vegetation-agrarian histories, thus postponing any regional or even general observations until the end of the qualitative analysis.[15] The advantage of applying numerical procedures lies in the possibility of diachronic comparisons of different agrarian and economic developments that took place in particular regions. This in turn makes it possible to grasp regional trajectories of key phenomena and processes in the economic history of Byzantium.

LATE ANTIQUITY AND THE EARLY MIDDLE AGES

In Central Greece, the period of Late Antiquity witnessed a noteworthy increase in cereals, lasting from AD 400 until ca AD 700, followed by an equally remarkable decrease which lasted until AD 850 (Figure 4). Importantly, cereals were not the only anthropogenic indicator that expanded during this period. In its first, more intensive phase (AD 400–550), the growth of cereals was accompanied by an increase in steppic vegetation, especially chenopods and grasses (Figure 7), as well as in ribwort plantain (a common weed) (Figure 6), which strongly suggests an opening of the landscape for pastures. Apart from cereals, another cultivar whose values grew in this period was olive (Figure 5). If we look beyond the plants representative of agricultural landscapes, we notice that this agrarian growth took place at the expense of oak. Its values decreased substantially during that initial phase of agrarian prosperity (AD 400–550) (Figure 8). After a century characterised by relatively stable values, oak started to expand again in AD 650, at the same time as both the pastoral indicators and olive commenced their decline. A few decades later, after AD 700, the decrease in cereals suggests that an increasing number of fields had been transformed into more or less forested landscapes.

Macedonia seems to have followed the same trajectory, at least initially. It is visible in the culmination of the growth in both cereals and walnut that occurs during the years AD 300–450 (Figure 9), some one hundred years earlier than in Central Greece. However, this growth is much better recorded on one site – Lailias, located on the eastern fringes of the Macedonian plain, in the Strymon valley (Map 1) – than on the others, to the west of the plain; it is also visible in the data from Western Bulgaria. A remarkable decline in cereals after AD 500 follows this late antique climax and continues until a low-level stabilisation sometime after AD 800, exactly the time when Central Greece experienced a similar decline and stabilisation in its cereal output. Interestingly, while the transition to the early Middle Ages in Greece is visible first in the expansion of forest vegetation, in the case of Macedonia we see a contrary phenomenon: after AD 500 forest trees (primarily alder, fir, and pine) continue to decline (Figure 12), while grasses and sedges gained in importance (Figure 11). Only after AD 750 was this trend reversed, with woodlands expanding and steppic indicators decreasing.

This scenario of agrarian change complements our knowledge of the settlement transformations that were taking place in the Greek and Macedonian countryside during the same period. In Late

[15] As conducted in Izdebski, A rural economy in transition.

Antiquity, there is abundant evidence for settlement expansion from all parts of Greece.[16] Starting from the south, in the western Peloponnese, the number of rural sites achieved their highest level during the fifth and sixth centuries.[17] In the southern Argolid there was a notable increase in the number of sites during roughly the same period (fourth to seventh centuries), an increase comparable to the settlement explosion of the Late Classical and Early Hellenistic periods (350–250 BC).[18] Similar ceramic data is available for eastern Corinthia. However, due to the visibility bias in favour of late Roman pottery, the scale of late antique settlement expansion in the countryside may not have been as massive as the raw data suggests.[19] On the Greek mainland, the countryside of Boeotia saw increased levels of settlement and exploitation in Late Antiquity, especially in the area around Thespiai (where rural settlement probably achieved its historical climax during this period)[20] or the valley of the Muses.[21] To the north, in Macedonia, rural settlement expanded not only on the easily accessible areas of the plain, but also in locations that were, from an environmental perspective, more marginal. This process is particularly visible in the Strymon valley, in proximity to the pollen site of Lailias.[22]

It is now worth taking a closer look at the changes that affected the rural economies of Greece and Macedonia in the early Middle Ages. The process of transition from the late antique into the early medieval period was different in each of the two regions. The four Central Greek sites saw a notable drop in economic activities and partial reforestation while, in the mountainous hinterland of Macedonia, there remained at first enough anthropogenic pressure to stop the expansion of forests that should have occurred once the intensive cultivation characteristic of Late Antiquity had declined substantially. It is worth noting that the difference between the regions of Central Greece and Macedonia – or rather, between these two clusters of pollen sites – is due not only to the variations in historical and geographical factors between these two parts of the Balkan peninsula; the four sites that cluster into Region A (Central Greece) are all located close to the coasts, where the Roman and Byzantine political and economic presence continued without major interruption. The areas in Region B (the Macedonian uplands), however, are located in the mountains that surround the large coastal plain. The situation of these two areas – Greek coasts and Macedonian highlands – was completely

[16] For an overview, see G. D. R. Sanders, Problems in Interpreting Rural and Urban Settlement in Southern Greece, AD 365–700, in: Landscapes of change: rural evolutions in late antiquity and middle ages, ed. N. Christie. Aldershot 2004, 163–193.

[17] A. Lambropoulou, Le Péloponnèse occidental a l'époque protobyzantine (IVe–VIIe siècles). Problèmes de géographie historique d'un espace à reconsidérer, in: Byzanz als Raum. Zu Methoden und Inhalten der historischen Geographie des östlichen Mittelmeerraumes im Mittelalter, ed. K. Belke – F. Hild – J. Koder – P. Soustal (*VTIB* 7). Wien 2000, 95–113.

[18] C. N. Runnels – T. H. van Andel, The Evolution of Settlement in the Southern Argolid, Greece: An Economic Explanation. *Hesperia* 56 (1987) 303–334.

[19] D. K. Pettegrew, The Busy Countryside of Late Roman Corinth: Interpreting Ceramic Data Produced by Regional Archaeological Surveys. *Hesperia* 76 (2007) 743–784.

[20] J. Bintliff – P. Howard – A. M. Snodgrass – O. T. P. K. Dickinson, Testing the hinterland: the work of the Boeotia survey (1989–1991) in the southern approaches to the city of Thespiai. Cambridge 2007.

[21] J. Bintliff, The archaeological survey of the Valley of the Muses and its significance for Boeotian History, in: La Montagne des Muses, ed. A. Hurst – A. Schachter. Genève 1996, 193–224; J. Bintliff, The Contribution of Regional Survey to the Late Antiquity Debate: Greece in its Mediterranean Context, in: The Transition to Late Antiquity: On the Danube and Beyond, ed. A. Poulter (*Proceedings of the British Academy* 141). Oxford 2007, 649–678; Bintliff, Central Greece in Late Antiquity.

[22] A. Dunn, Continuity and change in the Macedonian countryside from Gallienus to Justinian, in: Recent research on the late antique countryside, ed. W. Bowden – L. Lavan (*Late Antique Archaeology* 2). Leiden 2003, 535–585; A. Dunn, The problem of the early Byzantine village in eastern and northern Macedonia, in: Les villages dans l'empire byzantin: IVe–XVe siècle, ed. J. Lefort – C. Morrisson – J.-P. Sodini (*Réalités Byzantines* 11). Paris 2005, 267–278; A. Dunn, Rural producers and markets: aspects of the archaeological and historical problem, in: Material culture and well-being in Byzantium (400–1453), ed. M. Grünbart – E. Kislinger – A. Muthesius – D. Ch. Stathakopoulos (*Österreichische Akademie der Wissenschaften, philosophisch-historische Klasse, Denkschriften* 356 = *Veröffentlichungen zur Byzanzforschung* 11). Wien 2007, 101–109.

different, particularly with regard to the degree of Byzantine military or political control, and the ways in which these regions participated in the early medieval exchange networks.[23]

It is not surprising, therefore, that these two areas should have different environmental histories. Whereas, on the Greek coast, the final collapse of the Late Roman Balkans in the late sixth and early seventh centuries resulted in a significant decline in the agrarian economy only after AD 700, in the more mountainous parts of Greece and Macedonia, the old agrarian economy started to decline after AD 450. Moreover, while the old economy was collapsing, a new one was slowly beginning to emerge. This early decline (after AD 450) in cereals and the gradual opening of forested landscapes that followed in the early Middle Ages is also visible in the mountains of Western Bulgaria (Figures 13 and 16). Here the values of steppic vegetation began to grow after AD 600 (Figure 15), accompanied by the increasing presence of ribwort plantain (Figure 14). Concurrently with this growth, the presence of forest trees began a decline that would continue until the early modern period. This emerging rural economy is characterised by a considerably greater pressure on pastoral activities which may point to the Roman Vlachs (see the next section for a more detailed discussion). Another agricultural strategy that may have resulted in such a vegetation pattern might have been to keep large tracts of landscape open, without using all of it in every season; this would be similar to the agricultural strategies visible in the Lower Danube region, in areas of early Slavic settlement.[24] However, given the controversies surrounding the ethnic attribution of archaeological finds in Greece and Macedonia,[25] linking landscape types or vegetation patterns with particular ethnicities requires a different type of analysis (more qualitative in character), an analysis which, given the palynological and archaeological evidence currently available, may not even be possible.

As we move into Eastern Bulgaria, we encounter a region with a markedly different history of agrarian-economic developments. Here, we first observe signs of agrarian growth that continues until as late as AD 600–650 (cereals, grasses – Figures 17 and 19), or even AD 800 (vine, ribwort plantain – Figures 17 and 18): this may be interpreted as an increase in the scale of cultivation and pasturing, especially during the first three hundred years. A period of stagnation or even decline lasting some two centuries is clearly visible from around AD 800; values of cereals and ribwort plantain slightly decreased, while forest trees – especially oak and pine, typical for post-anthropogenic landscapes – expanded noticeably (Figure 20). It is not easy to link these developments to the political history of this region, or to what we know about its archaeology. In Late Antiquity, the Lower Danube Region – roughly comparable to Eastern Bulgaria – experienced a major transformation of its settlement pattern; the area, once dominated by cities and villae, became more militarised, with settlements focused on forts.[26] As a result of these changes, it appears that the economy contracted substantially. The fact that in 536 Justinian established a military administration called *quaestura exercitus* whose aim was to transport provisions for the Danube army from the Aegean and Cyprus would further confirm this interpretation;[27] Justinian's administrative measure suggests that, in the early sixth century, the

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[23] F. Curta, Still waiting for the barbarians? The making of the Slavs in "Dark-Age" Greece, in: Neglected Barbarians, ed. F. Curta. Turnhout 2011, 403–478; Idem, Were there any Slavs in seventh-century Macedonia? *Journal of History* 47 (2012) 61–74.

[24] F. Curta, The making of the Slavs: history and archaeology of the Lower Danube Region, ca. 500–700. Cambridge 2001, 276.

[25] As summarised by Curta, Still waiting for the barbarians? Idem, Were there any Slavs in seventh-century Macedonia?

[26] A. Poulter, The Transition to Late Antiquity, in: The Transition to Late Antiquity: On the Danube and Beyond, ed. A. Poulter (*Proceedings of the British Academy* 141). Oxford 2007, 1–50; F. Curta, Horsemen in forts or peasants in villages? Remarks on the archaeology of warfare in the 6th to 7th century Balkans, in: War and warfare in Late Antiquity, ed. A.C. Sarantis – N. Christie (*Late Antique Archaeology* 8). Leiden 2013, 809–850.

[27] A. H. M. Jones, The later Roman Empire: 284–602. A social, economic and administrative survey. Oxford 1964, 1, 280; F. Curta, Quaestura exercitus: the evidence of lead seals. *Acta Byzantina Fennica* 1 (2002) 9–26.

taxable agrarian output of this region must have been so small that it was no longer sufficient for the strong Roman army that defended the Danube frontier. The archaeological picture of the countryside is even more complicated as for the period that followed immediately. Whereas, in the seventh century, most of the Balkans – including some parts of Eastern Bulgaria – suffered demographic collapse,[28] in the eighth century one observes an increase in the number of burials (suggesting demographic growth) throughout the entire Lower Danube Region.[29]

In the context of such dramatic transformations, palynological evidence for the early Middle Ages in Eastern Bulgaria – as well as any regional reconstructions based on this data – is of very limited usefulness. This period is represented by an exceptionally low number of pollen samples (just 4 samples for AD 600–800, and only one sample for the entire fifth century; see Figure 3); furthermore, the sites that constitute this region are located in areas – the Black Sea coast, the Danube valley, and inland Thrace – that had different political histories after AD 550. Therefore, it is possible that our reconstructions reflect only the general direction of changes that took place over four centuries and that actually were much more complex than the diagram curves may suggest. We would thus see the transition from very low population levels in the sixth century to genuine demographic growth in the eighth century – which in this case should not be interpreted as a steady growth.

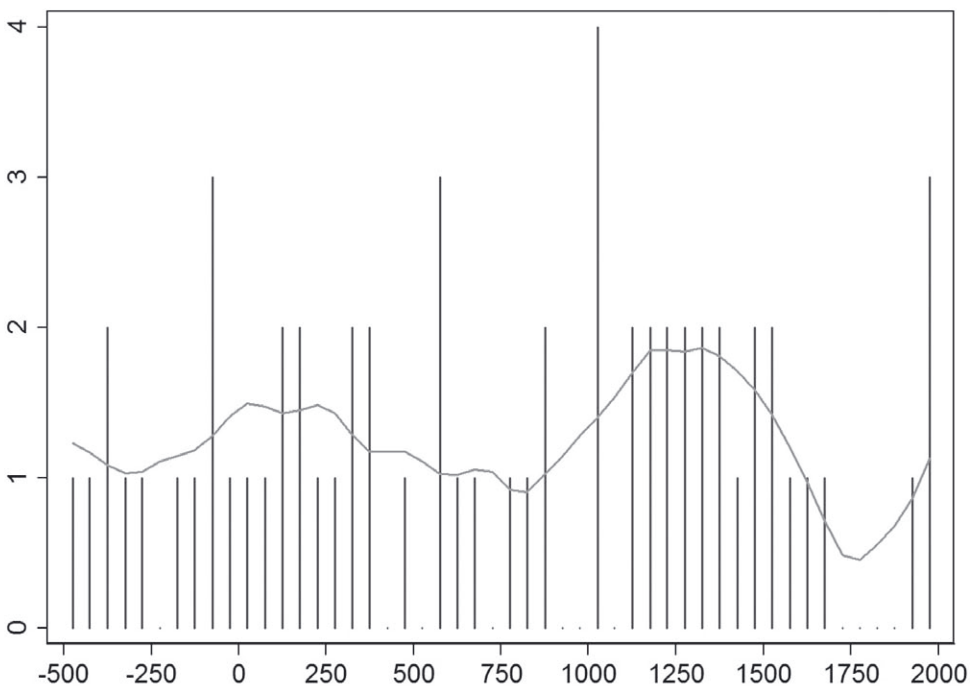

Figure 3. Number of pollen samples per 50 years in the palynological data from Eastern Bulgaria.

In Anatolia we can also find evidence of an intensive late antique agrarian economy, similar to what we see in Central Greece and Macedonia. The initial levels of cereals in Eastern Bithynia, Inland

[28] F. Curta, The beginning of the Middle Ages in the Balkans. *Mill* 10 (2013) 145–214.
[29] F. Curta, Southeastern Europe in the Middle Ages, 500–1250. Cambridge 2006, 89.

Pontus, and South-Western Anatolia were high compared to later periods in the same regions, yet their gradual decline began as early as AD 400, earlier than in Greece (Figures 21, 25 and 29). At the same time, however, the north of Anatolia witnessed a growth in other cultivars: vine and olive in Bithynia (Figure 21), walnut and vine in Pontus (Figure 25), culminating in both cases around AD 550–650, with slight interregional differences in chronology. Around AD 600, however, the signs of early medieval decline become clear. Forest trees started to expand rapidly: pine (on a massive scale) in Inland Pontus (Figure 28) and South-Western Anatolia (Figure 32), alder and several other trees in Eastern Bithynia (Figure 24). Concurrently, there was a decrease in other potential indicators of human activity: cereals, olive, vine, walnut, as well as secondary anthropogenic indicators (Figures 22, 26 and 30) and steppic vegetation (Figures 23, 27 and 31). The duration of this period of decline differed between the three regions represented in our database. It is least clearly expressed in the results obtained for Eastern Bithynia, where some revival of the agrarian economy – especially cereals and olive – is visible in the later part of Late Antiquity, AD 500–650; this is followed by a slow and prolonged decline in cereal cultivation, which eventually reached its lowest values around AD 1100. In Inland Pontus, the early medieval decline continued until AD 800–900, while in South-Western Anatolia it appears that the downward trend in the agrarian economy ended some one hundred years earlier (around AD 800).

This scenario of agrarian change is corroborated to some extent by the archaeological evidence. Unfortunately, much of the available evidence is limited to the south-western areas of Anatolia. Interestingly, the archaeological evidence suggests the fifth and sixth centuries were a period of prosperity for the countryside, at least judging from the intensive church construction and other building activity.[30] Two archaeological surveys from Pisidia, in particular, offer evidence for the expansion of rural settlement in Late Antiquity, one of which is based on a close analysis of ceramic finds.[31] In the area around Sagalassos, where some of the pollen sites included in our database were cored, Late Antiquity saw a gradual transformation in the rural settlement pattern (smaller settlements were clustering into villages[32]), but no apparent expansion in terms of the total settled area.[33] However, while the hinterlands of Sagalassos also offer evidence for small-scale settlement continuity between the late antique and early medieval periods,[34] in the Balboura plain all traces of settlement had disappeared completely by the end of the eighth century. In this context it is interesting to note that, on our figures for this area, the period of AD 400–600 is already characterised by diminishing values of agricultural indicators (and in this part of Anatolia, there are no visible signs of revival after AD 500!). This leads to the hypothesis that the settlement prosperity recorded by archaeologists reflects a new pattern of resource allocation rather than genuine, large-scale economic expansion; in

[30] A general survey: A. Izdebski, The economic expansion of the Anatolian countryside in Late Antiquity: the coast versus inland regions. *Late Antique Archaeology* 10 (2013) 343–376.

[31] J. J. Coulton, Late Roman and Byzantine Balboura, in: The Balboura Survey and settlement in Highland Southwest Anatolia. 1. Balboura and the history of highland settlement, ed. J. J. Coulton. London 2012, 163–184; the second survey is: L. Vandeput – V. Köse, Survey in the Taurus mountains: methodologies of the Pisidia survey project. *Late Antique Archaeology* 9 (2012) 205–245.

[32] In this period, similar processes occurred also elsewhere in South-Western Anatolia: F. Kolb, Burg – Polis – Bischofssitz. Geschichte der Siedlungskammer von Kyaneai in der Südwesttürkei. Mainz 2008, 406–417.

[33] H. Vanhaverbeke – F. Martens – M. Waelkens – J. Poblome, Late Antiquity in the territory of Sagalassos, in: Recent Research on the Late Antique Countryside, ed. W. Bowden – L. Lavan – C. Machado (*Late Antique Archaeology 2*). Leiden 2003, 247–280.

[34] H. Vanhaverbeke – A. K. Vionis – J. Poblome – M. Waelkens, What Happened after the 7th century AD? A different Perspective on Post-Roman Rural Anatolia, in: Archaeology of the countryside in medieval Anatolia, ed. T. Vorderstrasse – J. Roodenberg. Leiden 2009, 177–190.

other words, the countryside would have become increasingly important compared to urban settlements, without significant changes to the intensity of cultivation.[35]

With regard to the two northern regions, there is one survey – dealing with an area located on the coast of Paphlagonia, around Sinop, away from both of the analysed regions[36] – and one site, Çadır Höyük, close to Inland Pontus.[37] While Late Antiquity witnessed an impressive expansion of rural settlement in Sinop's hinterlands (which accords with the pollen data from the north of Anatolia), the peripheral site of Çadır Höyük, although it fared relatively well in this period, does not seem to show signs of notable expansion.

When we compare the results from the two parts of the Byzantine world – the Balkans and Anatolia – it becomes clear that, to a large degree, their rural economies followed the same general patterns of change. Both in Greece, Macedonia and Western Bulgaria, as well as in Anatolia, Late Antiquity is characterised by higher values of anthropogenic plants, although there seem to be two different chronologies: Central Greece and, to a lesser extent, northern Anatolia experienced prolonged agrarian expansion that becomes visible in later Late Antiquity (after AD 400) and lasts beyond AD 600. On the contrary, in South-Western Anatolia and Macedonia (and to some extent Western Bulgaria) it was earlier Late Antiquity (AD 300–400) that saw the culmination of Roman rural growth while later Late Antiquity (after AD 400) was a period of gradual decline. This demonstrates that, within the same general pattern of relatively prosperous Late Antiquity, economic trajectories of growth and decline could differ considerably by region. It is important to note that these differences cannot be explained solely in terms of political-military security, which becomes obvious when we contrast the reasonably safe Anatolia with the permanently endangered Balkans. These differences call for a more complex explanation, such as the one recently proposed by John Bintliff, who suggested that the astonishing complexity of the Late Roman world, despite apparent decline in some areas, was capable of sustaining or even encouraging substantial growth in other areas, a growth that would not necessarily express itself everywhere through exactly the same aspects of socio-economic life.[38]

On both sides of the Aegean, the end of Antiquity – either the late sixth or the mid-seventh century – marks the beginning of a substantial decline in the rural economy that lasts for at least two centuries. Thus, the amount of resources available for the state and its army after the middle of the seventh century fell drastically, and the seventh and eighth centuries seem to be the most difficult period of Byzantium's medieval history, at least in terms of its agrarian output.[39] It is worth mentioning that the lands which would eventually form the basis of the Bulgarian state had a separate history, known to us only partially. On one hand, we have a relatively reliable reconstruction of the vegetation history

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[35] The gradual decline of at least some of the Anatolian cities in the later part of Late Antiquity is a yet another argument in favour of this hypothesis. See P. Niewöhner, Archäologie und die "Dunklen Jahrhunderte" im byzantinischen Anatolien, in: Post-Roman towns, trade and settlement in Europe and Byzantium, ed. J. Henning. Berlin 2007, 119–158; L. Brubaker – J. F. Haldon, Byzantium in the Iconoclast era (ca 680–850): a history. Cambridge 2011, 544–549; on the divergence of archaeological and palynological data, see also a comparison of the Balboura survey results and the near-by pollen core of Gölhisar in J. Haldon *et alii*, The climate and environment of Byzantine Anatolia: integrating science, history and archaeology. *Journal of Interdisciplinary History* 45 (2014) 113–161; here as well the trends in the pollen of cultivated plants and rural settlement density have different trajectories in Late Antiquity.

[36] O. P. Doonan, Sinop landscapes: exploring connection in a Black Sea hinterland. Philadelphia 2004, 93–118.

[37] M. Cassis, Çadır Höyük: A Rural Settlement in Byzantine Anatolia, in: Archaeology of the countryside in medieval Anatolia 1–24.

[38] J. Bintliff, The paradoxes of Late Antiquity: a thermodynamic solution. *Antiquité Tardive* 20 (2012/–1) 69–73.

[39] Cf. the administrative measures undertaken by the Byzantine government to cope with this critical situation: W. Brandes, Finanzverwaltung in Krisenzeiten: Untersuchungen zur byzantinischen Administration im 6.–9. Jahrhundert (*Forschungen zur byzantinischen Rechtsgeschichte* 25). Frankfurt am Main 2002; Brubaker – Haldon, Byzantium in the Iconoclast era: a history 682–705.

for most of the central mountain ranges of the Balkans, where the early medieval period witnessed a slowly-paced intensification of economic activity, mostly focused on pasturing. On the other hand, the data from eastern Bulgaria shows a completely different pattern, which can only be loosely linked to the turbulent political and settlement history of this area.

THE PASTORAL ECONOMY OF THE BULGARIAN MOUNTAINS

At this stage it is already apparent that two of our regions – the highlands of Macedonia and Western Bulgaria – follow a different trajectory of environmental change than the other regions. As we have seen, a new agrarian economy started to emerge in the mountainous areas stretching from Pindus to the Stara Planina around AD 600; this development is visible first of all in the increase of steppic indicators (Figures 11 and 15) and, among the secondary anthropogenic indicators, ribwort plantain (Figures 10 and 14). The early Middle Ages were thus the starting point in the long development of a large-scale pastoral economy that persisted until the modern era. In this first phase, lasting from AD 600 until AD 1000, the most remarkable phenomenon is the growth in values of steppic vegetation: these are primarily sedges, accompanied to a certain degree by *Artemisia* and chenopods. At the same time, ribwort plantain increases its share in the pollen signal. The year AD 600 is also the beginning of a downward trend in the values of forest trees; initially, this decline is relatively slow. Most importantly, we may also note in this early period an increase in the values of cereals (clearly visible from AD 700 onwards), as well as vine and walnut (after AD 600). This suggests that the populations inhabiting these mountainous lands may have started to apply a wider range of agricultural strategies to exploit their demanding environments.[40]

A change occurred around AD 1000. At this point cereals started to decrease and their decline continued until AD 1300. The trends in other cultivated plants, vine and walnut, began their reversal even earlier, around AD 900, which suggests either that a cultural change took place and these items were no longer consumed in the same quantities, or that the items had started to be imported from the Western Bulgarian lowlands, the Macedonian plain or even from further south. The changes that started during this period can be interpreted as the beginning of specialisation in the pastoral economy: more focus was placed on pasturing, which is confirmed by the steady growth in ribwort plantain. Interestingly, this transformation coincides with the middle Byzantine economic revival, first in Greece and later in Macedonia and Eastern Bulgaria (see the next section). Thus, it seems that once exchange intensified and regional economic networks became more stable and reliable, populations inhabiting the central Balkan mountain ranges found it more advantageous to favour one type of agrarian activity – pasturing – above others.[41]

In the context of this intensification of mountain pasturing, as well as its emergent integration into the wider economic system, it is not surprising that people involved in this activity started to appear in the written record. The first few testimonies date to the eleventh century, the most notable of which is Kekaumenos's account of the Vlach (mountain pastoralists) rebellion of 1066/67. It is interesting to note that Byzantine authors are already aware of the system of transhumant pastoralism whose

[40] Unfortunately, there is hardly any archaeological material that would complement the palynological evidence on mountain pasturing in the early medieval period. Most of archaeological finds come from other locations and reflect different types of pastoral economies, cf. J. Henning, Südosteuropa zwischen Antike und Mittelalter (*Schriften zur Ur- und Frühgeschichte* 42). Berlin 1987, 102–105.

[41] For a discussion of how large-scale pastoral economies depended on well-developed exchange networks and presence of crop agriculture in their proximity, see P. Horden – N. Purcell, The corrupting sea: a study of Mediterranean history. Oxford 2000, 80–87.

development must have led to the vegetation change visible in the pollen data from Western Bulgaria.[42] Thus the pollen data makes it possible to see how, by the end of the twelfth century, the communities involved in this pastoral economy grew strong enough to support a victorious rebellion against the Byzantine authorities that led to the creation of the Second Bulgarian Empire (which the contemporary sources describe as the polity of the Vlachs, that is the transhumant or nomad pastoralists).[43]

The expansion of this specialised pastoral economy accelerated in the later Middle Ages, after two centuries of stagnation or decline following AD 1200. During this period (AD 1200–1400) the growth of steppic indicators slowed down, while forest values remained stable, contrary to the preceding centuries; cereals continued to decline until AD 1300. Remarkably, the values of walnut and vine start to rise at exactly the same time, and this growth continues even beyond AD 1400. This suggests that the process of specialisation visible in the Middle Byzantine period slowed down considerably meaning that, following the creation of the second Bulgarian Empire and the collapse of the Byzantine state after the Fourth Crusade, and the expansion of Serbia into the central Balkans in the later Middle Ages, the local populations of these mountain ranges had to modify their agricultural strategies. Although there are no signs of major economic contraction, a more diversified type of agriculture was preferred in response to the less secure political situation, which may have been perceived as causing troubles to both local and long-distance exchange. However, it is exactly during this period (from the thirteenth century onwards) that a larger amount of written evidence on transhumant pastoralism becomes available (which, of course, is due to the preservation of more recent archival material). Several late medieval Greek and Serbian documents confirm the presence of nomads in the Pirin mountains. They used lands located beyond village territories and cultivated fields, and are reported in particular to have raised their flocks in mountain pastures.[44]

Once the entire region became dominated by a single power – the Ottomans – in the two centuries between AD 1400 and AD 1600, the values of forest trees declined more than they had in the previous six to seven centuries. The growth of grasses continued without interruption, and the same can be said for *Artemisia*. Running almost parallel to the decrease in forest trees was a notable acceleration in the growth of the ribwort plantain values, which achieved their first peak in the sixteenth century, after AD 1500. Interestingly, this entire period (after AD 1400) also saw a renewed growth in cereals (which continued until AD 1700). This may suggest increased settlement pressure in the area as well as a reduced reliance on cereals purchased from lowland farmers. Thus, the late Byzantine pastoral economy persisted into the Ottoman period, and even seems to have developed further, as all anthropogenic indicators achieved their highest values in the eighteenth and nineteenth centuries. Moreover, it must have spread to other mountain ranges of the Balkans, as is apparent from the rise of secondary anthropogenic indicators on the sites surrounding the Macedonian plain, including the Pindus (the peak after AD 1600). This continued expansion of pastoral economy, combined with a notable change in agrarian practices (cereals increasing together with indicators of pasturing), may have been the result of an influx of new ethnic groups. Following the Ottoman conquest – during the fifteenth and, in particular, the sixteenth century – Turcoman nomads from Anatolia (*Yürükler*) settled in the Western Rhodopes and Eastern Macedonia, precisely in the area covered by the pollen

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42 For the earliest testimonies on transhumant Vlachs in Byzantine sources, see M. Gyóni, La transhumance des Vlaques balkaniques au Moyen Age. *BSl* 12 (1951) 29–42.

43 For a brief summary, with references to the primary sources, see Curta, The making of the Slavs 357–365; M. Ritter, Die vlacho-bulgarische Rebellion und die Versuche ihrer Niederschlagung durch Kaiser Isaakios II. (1185–1195). *BSl* 71 (2013) 162–210.

44 M. Popović, Spätbyzantinische Siedlungen und wlachische Transhumanz in den Flusstälern der Strumica und Kriva Lakavica, in: Südosteuropäische Romania: Siedlungs-/Migrationsgeschichte und Sprachtypologie. Romanistisches Kolloquium XXV, ed. W. Dahmen (*Tübinger Beiträge zur Linguistik* 532). Tübingen 2012, 227–240.

data from Region C. Although they quickly adapted to the specific central Balkan model of transhumant pastoralism, their presence would have certainly contributed to the stronger anthropogenic pressure on these mountain environments. In addition, their experience of nomad life in Anatolia – as well as an increasing ethnic and cultural complexity within the region that may have encouraged self-reliance among transhumant groups – at least partially explains the return of cereal cultivation, whose role had diminished considerably during the preceding centuries, that is the middle and late Byzantine periods.[45]

THE MIDDLE BYZANTINE ECONOMIC REVIVAL

In Central Greece the middle Byzantine economic revival started around AD 900. During the hundred years that followed, values of woodland indicators (mainly pine and oak) fell substantially, while steppic vegetation expanded considerably. If we move our attention to the more direct indicators of human activity – that is the proportionate values of the two common weeds of fields and pastures, common sorrel and burnet – we observe that both started to increase even before AD 900, and this growth accelerated significantly just before AD 1000. Interestingly, whereas cereals started their middle Byzantine growth (lasting until AD 1300) at a time when parallel trends were occurring in forest and steppic vegetation, vine and chestnut began their increase some one hundred years earlier, and achieved their highest values around AD 1000. All these changes took place roughly between AD 900 and AD 1000; this century must have seen a rapid environmental change, brought about by impressive economic expansion. Yet while the new agrarian landscape must have already achieved its mature form by the eleventh century, the growth in agrarian output must have continued, given the steady increase in cereals that lasted for the next three centuries. Interestingly, signs of the Middle Byzantine economic expansion do not become visible in the Macedonian highlands until as late as AD 1100. It is at this moment that the cereal curve starts to rise (as well as the steppic indicators), while a few decades earlier the expanding trend in woodland indicators had reversed after three centuries of growth.

In this case, there is a considerable body of both archaeological and written evidence concerning the economic expansion that was taking place in Byzantine Greece from the tenth century onwards. In Laconia, one may even talk about an 'explosion' of rural sites during the twelfth century; their number had already started to grow at least two centuries earlier.[46] In Corinth, the largest number of glazed wares – more costly than ordinary everyday ceramics used in the countryside – are dated to the same century.[47] In another part of the Peloponnesus, north-west of Argos, the Berbati-Limnes survey recorded the largest number of sites for the 12th–14th c.[48] In Central Greece, in the Tangarike (Boeotia), the settlement climax is dated to the 12th–13th c.[49] In Macedonia, our knowledge of middle Byzantine agrarian developments is based on a vast body of written evidence preserved in the Athos

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45 For a recent analysis with references to the older literature and the primary evidence, see E. Raduschev, Das "belagerte" Gebirge. *Bulgarian Historical Review* 33 (2005) 17–58.

46 P. Armstrong, The Survey Area in the Byzantine and Ottoman Periods, in: The Laconia survey: continuity and change in a Greek rural landscape, ed. W. G. Cavanagh – J. Crouwel – R. W. V. Catling – G. Shipley (*Annual of the British School in Athens / Supplementary Volume* 26). London 2002, 339–402.

47 G. Sanders, New relative and absolute chronologies for 9th to 13th century glazed wares at Corinth: methodology and social conclusions, in: Byzanz als Raum. Zu Methoden und Inhalten der historischen Geographie des östlichen Mittelmeerraumes 153–173.

48 M. Hahn, The early Byzantine to modern periods, in: The Berbati-Limnes archaeological survey, 1988–1990, ed. B. Wells – C.N. Runnels. Stockholm 1996, 345–451.

49 A. K. Vionis, Current Archaeological Research on Settlement and Provincial Life in the Byzantine and Ottoman Aegean: A Case-Study from Boeotia, Greece. *Medieval Settlement Research* 23 (2008) 28–41.

archives, which have been analysed by French and Greek historians over the past decades. Thus, it is possible to reconstruct the processes that led to the transformation of Macedonia – in particular the plain and the coast – into the densely populated agricultural region we see in the thirteenth and fourteenth centuries. This change seems to have started already during the tenth century, after the Byzantine reconquest of this territory.[50] In addition, there is a general survey of the Byzantine economy in the middle Byzantine period, in AD 900–1200, which is based primarily on written evidence from Greece (which is more abundant than the Anatolian written record for the same period). It studies different economic phenomena, including the territorial expansion of agriculture, and leaves no doubt that this period witnessed impressive economic growth within the Byzantine Empire.[51]

In Eastern Bulgaria, the economic expansion of the middle Byzantine period started after AD 1000, later than in Central Greece. Here we may also observe a two-centuries long decrease in forest trees (especially oak, the tree that expanded most noticeably during the two preceding centuries of economic decline). During this period of forest clearance, we can also observe a rise in the secondary anthropogenic indicators, burnet and ribwort plantain. With regard to cultivated plants, three of them began to rise around AD 1000: vine and chestnut continued their growth for another three centuries, while cereals expanded without interruption until the fifteenth century. This late beginning of the economic revival in Eastern Bulgaria – as compared to Central Greece – can certainly be explained by political events. It was only towards the end of the tenth century that this region became part of the Byzantine Empire, when the Bulgarian state was conquered by John Tzimiskes and Basil II.[52] These same events may also have been the reason for the belated beginning of economic expansion in the Macedonian highlands. As for Eastern Bulgaria, conditions were still rather unfavourable in the mid-eleventh century (the region suffered major invasions whose results are visible in the archaeological record[53]), whereas there is much archaeological material (numerous hoards) and written evidence (mostly related to the Crusades and focused on the area around Philippopolis) suggesting that, by the twelfth century, Thrace was rather wealthy and its agrarian output was relatively high.[54]

In Anatolia, we observe the same phenomenon, but with a different chronology. Most importantly, the economic revival started here some one hundred years earlier than in Greece. In South-Western Anatolia especially, cereals had already begun their expansion by around AD 800, following the period of early medieval decline; around the same time the values of both chestnut and walnut began to rise and some slight increase is also visible in the case of olive. With regard to the less direct indicators of economic activity – the two common weeds, ribwort plantain and burnet – both of them experienced a notable increase in AD 800–1000, and this growth continued on a lesser scale throughout the next hundred years. At the same time, there was a massive increase in the presence of grasses, reaching its culmination in the eleventh century. Unsurprisingly, between AD 800 and AD 1050 there is a visible drop in forest trees, mostly pine, which expanded during the preceding period of agrarian decline.

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[50] J. Lefort, En Macédoine orientale au Xe siècle: habitat rural, communes et domaines, in: Occident et Orient au Xe siècle. Paris 1979, 251–272; J. Lefort, L'organisation de l'espace rural: Macédoine et Italie du sud (Xe–XIIIe siècle), in: Hommes et richesses dans l'Empire byzantine (*Réalités Byzantines* 1). Paris 1991, 11–26; J. Lefort, Rural Economy and Social Relations in the Countryside. *DOP* 47 (1993) 101–113.

[51] A. Harvey, Economic Expansion in the Byzantine Empire, 900–1200. Cambridge 1989, for the agrarian expansion, see esp. pp. 120–162; the written sources on the early phase of the agrarian expansion are also discussed in M. Kaplan, Les hommes et la terre à Byzance du VIe au XIe siècle: propriété et exploitation du sol (*Byzantina Sorbonensia* 10). Paris 1992, 531–539; for a recent overview of all the evidence for the Middle Byzantine economic prosperity, see Whittow, The Middle Byzantine Economy.

[52] M. Whittow, The making of Orthodox Byzantium, 600–1025. Berkeley 1996, 386–390.

[53] B. Borisov, Demographic and ethnic changes during XI–XII century in Bulgaria. *Archaeologia Bulgarica* 11 (2007) 71–84.

[54] Curta, Southeastern Europe in the Middle Ages 321–323.

The picture becomes less clear when we turn our attention to the north of Anatolia. In Inland Pontus, there is a clear rising trend in cereals that lasts from ca AD 850 until ca AD 1050. Importantly, it is not accompanied by parallel changes in other anthropogenic indicators or forest vegetation, yet there is some rise in burnet and common sorrel. In this context, it is worth making two observations: first, forests – or rather, pine – started to decline as late as the eleventh century (after AD 1000); second, the rise in sedges, later followed by other steppic indicators, also began only after AD 1000. Thus, growth in Inland Pontus during the middle Byzantine period seems to have been of a limited nature, and the agrarian economy of this era seems dominated by cereal cultivation. In Eastern Bithynia, the decline of cereals continued steadily from AD 650 until AD 1100, while vine and olive expanded only from AD 900 until AD 1000, followed by a century or two of stagnation. Interestingly, we may also note a rapid increase in ribwort plantain lasting from as early as AD 750 until ca AD 925. Following an equally rapid decline, the trend of ribwort plantain reached its lowest values in AD 1150.

In the three regions of Anatolia represented in our database, AD 1100 represents an important watershed, marking the end of the middle Byzantine economic expansion (although not necessarily of economic development; see the following section). In South-Western Anatolia and Inland Pontus, where the middle Byzantine revival is visible in the palynological data, this period of increasing economic activity did not last beyond the eleventh century. In Eastern Bithynia, this same century can be considered the end of the long process of decline in the agrarian economy that began in Late Antiquity; in this region, the decline does not seem to have been significantly reversed by any agrarian growth in the ninth or tenth centuries. Given the possible estimation errors of the chronologies involved in our reconstructions, it is possible that the visible developments of AD 1100 may have coincided with the arrival of the Turks in Anatolia, which had started a few decades earlier. It is therefore probable that the chaos resulting from the Byzantine defeat at the hand of the Seljuks and the parallel migration of Turkic nomads into Anatolia brought about an end to the medieval economic revival in this part of the Byzantine world.[55]

Contrary to the situation in Greece, there is very little direct archaeological or written evidence from Anatolia to confirm this picture. It is possible, however, to point out some processes of social change that must have accompanied the agrarian growth in Anatolia which, in turn, was probably part of a more general economic expansion.[56] The tenth and eleventh centuries saw the emergence of a new powerful aristocracy within Byzantine society, whose position was based not only on its involvement in the power structures of the state, but also on its own landed wealth.[57] On the basis of the written sources from throughout the Byzantine world, it is possible to reconstruct the economic function of these aristocratic estates which gradually transformed the social landscape of the Byzantine countryside.[58] In addition to that, there is one region in Anatolia – unfortunately, not represented in our palynological database – from which we have archaeological material dated to this period that can be interpreted as remains of aristocratic estates. It has recently been argued that at least some of the numerous cave complexes of Cappadocia – commonly known as 'monasteries'

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[55] Cf. J.-C. Cheynet, La résistance aux Turcs en Asie Mineur entre Manzikert et la Première Croisade, in: Eupsychia: mélanges offerts à Hélène Ahrweiler (*Byzantina Sorbonensia* 16). Paris 1998, 131–147.

[56] Again, see Harvey, Economic Expansion in the Byzantine Empire; Whittow, The Middle Byzantine Economy; as well as M. F. Hendy, Studies in the Byzantine monetary economy, c. 300–1450. Cambridge 1985, 506–519.

[57] For a socio-political analysis, see J.-C. Cheynet, L'aristocratie byzantine (VIIIe–XIIIe siècle). *Journal des Savants* (2000) 281–322; see also the discussion in P. Frankopan, Land and Power in the Middle and Later Period, in: A social history of Byzantium, ed. J. F. Haldon. Oxford 2009, 112–142.

[58] Kaplan, Les hommes et la terre à Byzance 281–444.

– must have been centres of agricultural production rather than just peasant villages.[59] Although we have only one pollen site from all of Cappadocia – Lake Nar – its highly reliable pollen record demonstrates that, around this lake, there occurred substantial expansion of cereal cultivation and pasturing in the tenth and eleventh centuries.[60] It is thus possible to establish a link between agrarian expansion and the rise of aristocracy in Anatolia.

To sum up, the middle Byzantine economic revival is visible in several different parts of the Byzantine world, and can be understood as a general phenomenon characteristic of this period of Byzantium's economic history. Nonetheless, there are substantial differences between Greece, Eastern Bulgaria, and Anatolia, in both the chronology and the scale of the economic expansion. Thus, the growth in agrarian output started earliest in Anatolia (ninth century), then in Greece (tenth century) and even later in Bulgaria (eleventh century) or the Macedonian highlands (eleventh-early twelfth century). These starting dates coincide with the first decades of social and political stability in these regions. Whereas South-Western Anatolia and Inland Pontus were first to enjoy relative security, Eastern Bulgaria was the last one to join the world of the Pax Byzantina. However, not only did the agrarian expansion start in Anatolia much earlier than in the Balkans, but it also ceased two centuries before it came to an end on the other side of the Aegean. It seems to have been stopped abruptly by the coming of the Turks. These differences in the trajectory of economic development between Anatolia and Greece – as well as Eastern Bulgaria – are also visible in the material record. Even though our archaeological knowledge of middle Byzantine Greece is incomparable to the state of research on Anatolia in the same period, there are some grounds to claim that, while numerous impressive buildings were constructed in Greece and elsewhere in the Balkans during this period, there is much less architecture of a similar type that survives from Anatolia[61] except, of course, for Cappadocia. It can thus be concluded that, in the longer term, the chronology of the middle Byzantine economic expansion was strongly dependent on political events.

The scale of changes in agrarian output is also strikingly different from region to region, especially the levels of growth for cereals. While in South-Western Anatolia the proportionate values of cereals in the middle Byzantine period were considerably lower than those in Late Antiquity, Central Greece presents a different picture. Here, the middle Byzantine levels were considerably higher than those in Late Antiquity. If we compare Central Greece with both South-Western Anatolia and Eastern Bithynia, the same can be said of vine, olive and chestnut. Of course, due to the character of our data, these differences cannot be considered to be determined only by the increasing or declining total area of land under cereal or vine cultivation. Since we analyse proportionate and not absolute values, and since the pollen productivity of different plants is not identical, changes in one plant's distribution across the landscape can have influence on how other plants are represented in the total pollen sum. However, the differences we have just noted are large enough to at least attempt at their

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[59] R. G. Ousterhout, Questioning the archaeological evidence: Cappadocian monasteries, in: Work and worship at the Theotokos Evergetis, 1050–1200, ed. M. Mullet – A. Kirby. Belfast 1998, 420–431; V. Kalas, Rock-cut Architecture from the Peristrema Valley. Society and Settlement in Byzantine Cappadocia. (Unpublished PhD dissertation) New York University 2000. For the textual evidence on the landed aristocracy in Cappadocia, see M. Kaplan, Les grands propriétaires de Cappadoce (VIe–XIe siècles), in: Le aree omogenee della civiltà rupestre nell'ambito dell'impero bizantino: la Cappadocia: atti del quinto Convegno internazionale di studio sulla civiltà rupestre medioevale nel Mezzogiorno d'Italia (Lecce-Nardò, 12–16 ottobre 1979), ed. C.D. Fonseca. Galatina 1981, 125–158; M. Decker – J. E. Cooper, Life and society in Byzantine Cappadocia. Basingstoke 2012, 228–252.

[60] England *et alii*, Historical landscape change in Cappadocia.

[61] P. Niewöhner, What Went Wrong? Decline and Ruralisation in Eleventh Century Anatolia. The Archaeological Record, in: Eleventh-Century Byzantium. Social Change in Town and Country, ed. J. Howard-Johnston – M. Whittow. Oxford [in press].

interpretation. It seems, therefore, that the middle Byzantine economic revival in Greece (and Eastern Bulgaria) not only lasted longer, but was also more pronounced, resulting in the achievement of higher levels of economic development and wealth. In this context, it is worth asking whether these differences in this relative scale of agrarian output can lead to any inferences about the demographic situation. Traditionally, it is believed that demographic growth in Byzantine lands started in the tenth century and lasted, in some areas, until as late as the outbreak of the Black Death in the fourteenth century.[62] There is no doubt that our results confirm this view, in particular given the widespread conviction that changes in agrarian output in Byzantium depended on the increase or decrease in population levels in the countryside.[63]

THE LATER MIDDLE AGES AND THE OTTOMAN ERA

The two preceding sections – on Late Antiquity and the middle Byzantine period – demonstrate that several environmental and economic phenomena were visible throughout the Byzantine world, as they were experienced by almost every region that was integrated (more or less) into its economic system. By contrast, the particular regions seem to have followed much more diverse trajectories in the later Middle Ages. In Central Greece – and, in particular, Macedonia – we observe a decline in cereals and secondary indicators starting after AD 1300 or, more precisely, around the middle of the fourteenth century. This is not surprising given that, in the course of the fourteenth century, both regions were seriously affected by the Black Death[64] as well as by the social unrest resulting from the actions of the Latin military units such as the Catalan Company (sources record peasants escaping from war zones in the Peloponnesus and the Greek mainland[65]). It is worth noting that, while our approach was capable of detecting the environmental impact of the Black Death in the fourteenth century – a remarkable drop in the cereal curves in Central Greece and Macedonia – it did not detect any such impact in the case of the Justinianic Plague in the sixth century.[66] There is no equally obvious downward reversal of anthropogenic trends in the mid-sixth century, nor even during the entire period between AD 500 and 600, in particular not in the cereals which, of all the vegetation indicators provided by pollen data, have the most direct relationship with the demographic situation. This difference cannot simply be attributed to the difference in the quality of data between the two periods, since the probable impact of the Black Death is recorded in the two regions whose data sets are relatively reliable. However, this should not be interpreted to mean that the Justinianic Plague had

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[62] For instance, J. Lefort, Population et peuplement en Macedoine orientale, IXe–XVe siecle, in: Hommes et richesses dans l'Empire byzantine 69–71 or A. E. Laiou, The human resources, in: The Economic History of Byzantium: From the Seventh through the Fifteenth Century, ed. A. E. Laiou (*DOS* 39). Washington, D.C. 2002, 47–55. This view seems to be confirmed by settlement archaeology, at least in Laconia: Armstrong, The Survey Area.

[63] J. Lefort, The rural economy, seventh-twelth centuries, in: The Economic History of Byzantium 232–310; Harvey, Economic Expansion in the Byzantine Empire 120–162.

[64] M. W. Dols, The second plague pandemic and its recurrences in the Middle East: 1347–1894. *Journal of the Economic and Social History of the Orient* 22 (1979) 162–189. In Laconia, settlement density became reduced in the Late Byzantine period (AD 1204–1460) as compared to the two preceding centuries: Armstrong, The Survey Area. A fourteenth-century depopulation in the countryside is also attested for Macedonia (in the Athos archieval material): B. Geyer, Esquisse pour une histoire du paysage depuis l'An Mil, in: Paysages de Macédoine 99–116; Lefort, Population et peuplement.

[65] D. Jacoby, Peasant Mobility across the Venetian, Frankish and Byzantine Borders in Latin Romania, Thirteenth-Fifteenth Centuries, in: I Greci durante la venetocrazia: uomini, spazio, idee (13–18 sec.): atti del Convegno internazionale di studi, Venezia, 3–7 dicembre 2007, ed. D. Vlassi – C. Maltezou – A. Tzavara. Venezia 2009, 525–539.

[66] For the recent debate on the Justinianic Plague, see D. C. Stathakopoulos, Famine and pestilence in the late Roman and early Byzantine Empire: a systematic survey of subsistence crises and epidemics (*Birmingham Byzantine and Ottoman Monographs* 9). Aldershot – Burlington 2004; Plague and the end of antiquity: the pandemic of 541–750, ed. L. L. Little. Cambridge 2007.

no impact on society and economy in Late Antiquity; rather it suggests that the Justinianic Plague differed from the Black Death in its environmental and socio-economic impact. The damaging impact of the Justinianic plague was felt over a longer period of time, and its effects are very difficult to isolate from the other factors that contributed to the collapse of the late antique world.

After this period of contraction in the fourteenth century, agrarian growth did not resume in the early modern period. Moreover, the decrease in cereals and other anthropogenic vegetation was paralleled by an increase in steppic indicators. This may be a signal of a secondary succession of steppic vegetation into uncultivated cereal fields. The only early modern phenomenon to which we may wish to give special attention is the deforestation that seems to have taken place in Central Greece prior to AD 1600, and in the Macedonian highlands in AD 1500–1700. It probably indicates an intensive cutting of forests. In Eastern Bulgaria, on the contrary, the growth of the cereal values continued until AD 1500, after which they declined for the next two hundred years, up to AD 1700. Interestingly, a change in the focus of arboriculture also seems to have occurred in the fourteenth century. Vine, which expanded during the middle Byzantine period, declined markedly in AD 1300–1500, while walnut values visibly increased during these two centuries. The same happened to vine in Eastern Bithynia after AD 1350, and a century later (after AD 1450) in Inland Pontus, where walnut expanded from AD 1350 until AD 1600. This may reflect a cultural change relating to the Ottoman conquests and the spread of Islam in these regions. This is the only phenomenon visible in the reconstructions from both the Balkans and Anatolia in the late Byzantine period.

Despite these similarities, Inland Pontus generally offers a contrast with Greece; in the former region one may observe several signs of economic expansion during the later Middle Ages. This process seems to have started in the eleventh century, with pine giving way to steppic vegetation from as early as AD 1000. It culminated in AD 1200–1400, when we observe a rapid increase in all three secondary anthropogenic indicators, most notably in ribwort plantain. A parallel growth of steppic indicators at the expense of woodlands is also visible in Eastern Bithynia from AD 1200 until AD 1500, yet here it is not accompanied by a clear increase in common weeds. Around the same time in Inland Pontus – after AD 1200 – cereals and vine started to rise, followed by walnut a hundred years later. This new agrarian structure was maintained without substantial interruption until at least AD 1700–1800, although values of walnut and vine decreased in the early modern period. As we have already noted, vine in particular appears to have been a cultivar specific to the later Middle Ages in Northern Anatolia, enjoying increased popularity from the thirteenth until the fifteenth century. This phenomenon may also be observed in Eastern Bithynia; indeed, in this region, vine is the only anthropogenic indicator whose values rose during the later medieval period, from AD 1200 until AD 1400. The fifteenth and sixteenth centuries (AD 1400–1600) may be interpreted as a period of some economic contraction in Inland Pontus, especially with regard to pasturing: pine expanded at the expense of steppic vegetation. This suggests that the local political and economic context was an important factor contributing to this late medieval agrarian growth.

Indeed, the agricultural expansion in Inland Pontus began at the time when the role that the Black Sea coast of Anatolia played in the Mediterranean and Middle Eastern trade networks started to increase, as the Seljuks gained access to the Black Sea by conquering Sinop in AD 1214 and the Byzantine dynasty of the Komneni established their empire in exile in Trabzond in AD 1204. Throughout the thirteenth century, the trade between the Black Sea coast and Iraq, Iran or Central Asia on one hand, and the key centres of the Mediterranean was continuously growing. The Empire of Trebizond became a major exchange centre,[67] while several caravanserais were being constructed in the inland

[67] S. P. Karpov, Istoriya Trapezundskoi imperii. Sankt-Petersburg 2007.

of north-eastern Anatolia.[68] Thus, the cities of Amasya, Tokat and Sivas flourished, which must have encouraged agricultural production in the areas where the pollen sites of Inland Pontus are located, as they formed the rural hinterlands of these thriving urban centres. Interestingly, although the area represented in our database never belonged to the Empire of Trebizond, the type of agriculture visible in our data is exactly what we find in the region of Matzouka, the mountainous hinterlands of Trebizond, during the same period. Nuts were the cash crop of the local agrarian economy, while Pontic vine was appreciated in the Black Sea region and beyond.[69]

Compared to the north of Anatolia, the inland areas of its south-western part remained a backwater. This is plainly visible in the very low values of anthropogenic indicators in the period that followed the end of the middle Byzantine agrarian economy around AD 1100 (in comparison to previous periods in the same region). The only noteworthy phenomenon is the increase in ribwort plantain and chestnut – which may be observed between AD 1300 and AD 1500 – paralleled by decrease in pine. This suggests that some economic activity was taking place here as well, primarily of a pastoral character. It cannot however be compared to the developments that were taking place in Northern Anatolia during the same period. As for Eastern Bulgaria in the early modern period – most notably in the sixteenth century – this region was an important source of food supply for the great metropolis of Istanbul.[70]

To conclude, the processes that are visible across the different regions of the Byzantine world in the later Middle Ages would have brought about a substantial economic restructuring. In the Ottoman Balkans and Anatolia, an economic geography different from that of the middle Byzantine period began to emerge. Greece and South-Western Anatolia – the two regions that showed the most pronounced signs of the middle Byzantine economic expansion following the early medieval contraction – were either stagnant or completely peripheral during the Ottoman period. By contrast, Northern Anatolia and Eastern Bulgaria had gained in importance. This change was caused, in all probability, by both political and natural factors. South-Western Anatolia lost the strategic importance it enjoyed in Late Antiquity and the Byzantine Middle Ages, while the proximity of Inland Pontus to the Empire of Trebizond and its maritime networks may have provided a stimulus for agrarian expansion. Moreover, there is some scientific evidence to suggest that, in both Late Antiquity[71] and the middle Byzantine period,[72] the climate of the south-western part of Anatolia had started to improve; humidity increased and mean temperatures became slightly higher. Such changes had the potential to facilitate agrarian growth in both of these earlier periods, while nothing of this sort seems to have occurred in either the late medieval or early modern periods. On the contrary, the sixteenth

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[68] P. Blessing, Rebuilding Anatolia after the Mongol Conquest. Islamic Architecture in the Lands of Rum, 1240–1330 (*Birmingham Byzantine and Ottoman Monographs* 17). Aldershot 2014, 165–203.

[69] A. Bryer, Rural society in Matzouka, in: Continuity and change in late Byzantine and early Ottoman Society, ed. A. Bryer – H. Lowry. Washington, D.C. 1986, 53–95.

[70] R. Murphey, Provisioning Istanbul: The state and subsistence in the early Modern Middle East. *Food and Foodways* 2 (1987) 217–263.

[71] See overviews in: Izdebski, Why did agriculture flourish in the late antique East?; Izdebski, A rural economy in transition 132–143; Haldon *et alii*, The climate and environment of Byzantine Anatolia.

[72] W. J. Eastwood – M. J. Leng – N. Roberts – B. Davis, Holocene climate change in the eastern Mediterranean region: a comparison of stable isotope and pollen data from Lake Gölhisar, southwest Turkey. *Journal of Quaternary Science* 22 (2007) 327–341; J. Bakker *et alii*, Numerically derived evidence for late-Holocene climate change and its impact on human presence in the southwest Taurus Mountains, Turkey. *The Holocene* 22 (2012) 425–438; I. Heinrich *et alii*, Winter-to-spring temperature dynamics in Turkey derived from tree rings since AD 1125. *Climate Dynamics* 41 (2013) 1685–1701; see also the isotope-based reconstruction from Lake Nar in Cappadocia: M. D. Jones – C. N. Roberts – M. J. Leng – M. Türkeş, A high-resolution late Holocene lake isotope record from Turkey and links to North Atlantic and monsoon climate. *Geology* 34 (2006) 361–364.

century saw the onset of the Little Ice Age.[73] As for Greece, it experienced demographic as well as political turbulence in the later Middle Ages from which it does not seem to have fully recovered in the later period.

CONCLUSION

The current paper has presented the results of a project whose goal was to provide information on regional economic trends in the Byzantine and Ottoman period, as revealed by palynological data available for specific areas of the Balkans and Anatolia. To this end, we prepared a database with all the available palynological information from this part of the world (the Eastern Mediterranean; to this database, we then applied methods of numerical analysis which we developed specifically for this type of data. In this way we were able to obtain regional reconstructions of changes in a wide range of plant taxa for Greece, Bulgaria, and Anatolia. The results provide information on the late antique intensification of agrarian economy, especially in Greece and Macedonia, and on the middle Byzantine economic revival. They also shed some light on the restructuring of the Balkan-Anatolian world that took place during the later Middle Ages and resulted in a new economic geography during the Ottoman period. Our results, however, are not free from problems arising from the quality of the data (especially concerning chronological reliability and actual temporal resolution), as well as from the amount and geographical distribution of pollen sites on which we could base our analyses. Consequently, the interpretations presented in this paper have remained rather cautious, contrary to the results obtained from a much better pollen database collected for Central Europe, which allowed for more detailed analyses and more assured conclusions. Despite these limitations, the reconstructions that were possible for the Balkans and Anatolia offer valuable insights into the regional differentiation in Byzantium's economic history and demonstrate the potential of integrating scientific evidence into historical research.

[73] See the overview of the palaeoclimatic evidence in S. White, The Climate of Rebellion in the Early Modern Ottoman Empire. Cambridge 2011, 126–139.

APPENDIX 1

Original publications of the sites included in the database or publications of their age-depth models used in this study.

N. Athanasiadis, Zur postglazialen Vegetationsentwicklung von Litochoro Katerinis und Pertouli Trikalon (Griechenland). *Flora* 164 (1975) 99–132.

J. Bakker *et alii*, Man, vegetation and climate during the Holocene in the Territory of Sagalassos, Western Taurus mountains, SW Turkey. *Vegetation History and Archaeobotany* 21 (2012) 249–266.

S. Bottema, Late quaternary vegetation history of North-Western Greece. (PhD dissertation) University of Groningen 1974.

S. Bottema – H. Woldring, Late quaternary vegetation and climate of southwestern Turkey. Part II. *Palaeohistoria* 26 (1984) 123–149.

S. Bottema – H. Woldring – B. Aytug, Late Quaternary vegetation history of northern Turkey. *Palaeohistoria* 35/36 (1993/94) 13–72.

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W. Eastwood *et alii*, Holocene environmental change in southwest Turkey: a palaeoecological record of lake and catchment-related changes. *Quaternary Science Reviews* 18 (1999) 671–695.

W. Eastwood *et alii*, Holocene climate change in the eastern Mediterranean region: a comparison of stable isotope and pollen data from Lake Gölhisar, southwest Turkey. *Journal of Quaternary Science* 22 (2007) 327–341.

M. Filipova-Marinova, Palaeoecological investigations of lake Shabla-Ezeretz in north-eastern Bulgaria. *Ecologia mediterranea* 11 (1985) 147–158.

A. Gerasimidis – N. Athanasiadis, Woodland history of northern Greece from the mid Holocene to recent time based on evidence from peat pollen profiles. *Vegetation History and Archaeobotany* 4 (1995) 109–116.

A. Gerasimidis *et alii*, Contributions to the European Pollen Database. 4. Mount Paiko (northern Greece). *Grana* 47 (2008) 316–318.

A. Gerasimidis *et alii*, Contributions to the European Pollen Database. 8. Mount Voras (north-West Greece). *Grana* 48 (2009) 316–318.

A. Gerasimidis – S. Panajiotidis, Contributions to the European Pollen Database. 9. Flambouro, Pieria Mountains (northern Greece). *Grana* 49 (2010) 76–78.

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A. Izdebski, A Rural Economy in Transition. Asia Minor from Late Antiquity into the Early Middle Ages (*Journal of Juristic Papyrology*, *Supplement* 18). Warsaw 2013.

S. Jahns, On the Holocene vegetation history of the Argive Plain (Peloponnese, southern Greece). *Vegetation History and Archaeobotany* 2 (1993) 187–203.

S. Jahns, The Holocene history of vegetation and settlement at the coastal site of Lake Voulkaria in Acarnania, western Greece. *Vegetation History and Archaeobotany* 14 (2005) 55–66.

D. Kaniewski *et alii*, A high-resolution Late Holocene landscape ecological history inferred from an intramontane basin in the Western Taurus Mountains, Turkey. *Quaternary Science Reviews* 26 (2007) 2201–2218.

K. Kouli, Vegetation development and human activities in Attiki (SE Greece) during the last 5,000 years. *Vegetation History and Archaeobotany* 21 (2012) 267–278.

K. Kouli – M. D. Dermitzakis, Contributions to the European Pollen Database. 11. Lake Orestiás (Kastoria, northern Greece). *Grana* 49 (2010) 154–156.

M. Lazarova, Human impact on the natural vegetation in the region of Lake Srebarna and mire Garvan (northeastern Bulgaria). Palynological and Palaeoethnobotanical evidence, in: Advances in Holocene Palaeoecology in Bulgaria, ed. E. Bozilova – S. Tonkov. Sofia – Moscow 1995, 47–67.

M. Lazarova *et alii*, Contributions to the European Pollen Database. 6. Peat-bog Begbunar (Osogovo Mountains, south-west Bulgaria): Four millennia of vegetation history. *Grana* 48 (2009) 147–149.

M. Lazarova *et alii*, Contributions to the European Pollen Database. 12. Western Rhodopes Mountains (Bulgaria): peat bog Beliya Kanton. *Grana* 50 (2011)162–164.

S. I. Petrov – L. Filipovitch, Postglacial changes of the vegetation on the slopes of Sredna Gora mountain, in: Proceedings of the National Conference of Botany (Bulgaria). Sofia 1987, 339–406.

I. Stefanova – E. Bozilova, Studies on the Holocene history of vegetation in the Northern Pirin Mountains, southwestern Bulgaria, in: Advances in Holocene Palaeoecology in Bulgaria, ed. E. Bozilova – S. Tonkov. Sofia – Moscow 1995, 9–31.

S. Tonkov *et alii*, Contributions to the European Pollen Database. 7. Mire Straldza (Southeastern Bulgaria): Late Holocene vegetation history. *Grana* 48 (2009) 235–237.

W. van Zeist – H. Woldring – D. Stapert, Late quaternary vegetation and climate of southwestern Turkey. *Palaeohistoria* 17 (1975) 53–144.

APPENDIX 2: FIGURES

Please note: in the cumulative figures the top-down sequence of pollen indicators is reflected in the left-right sequence of the information given in the legend, line by line.

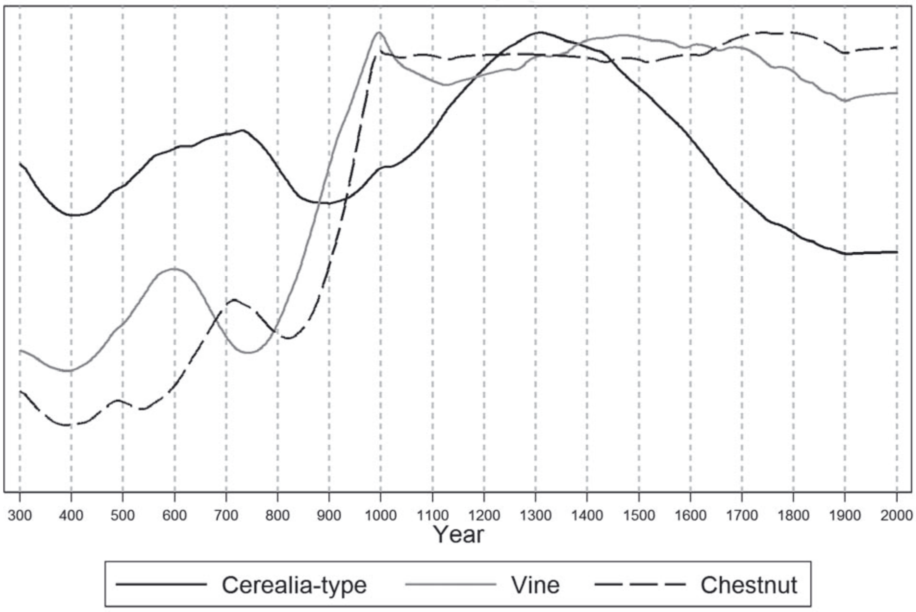


Figure 4. Central Greece: anthropogenic indicators

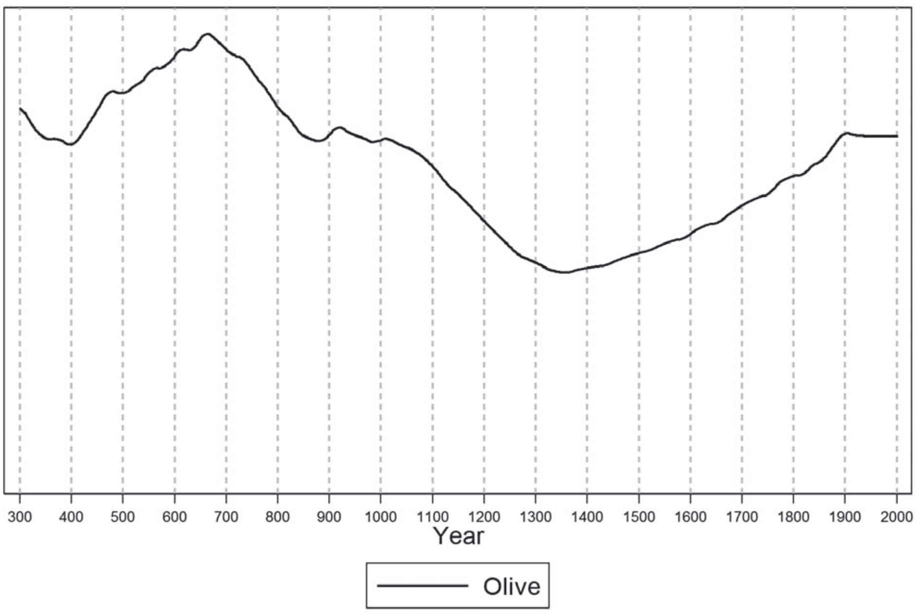


Figure 5. Central Greece: olive

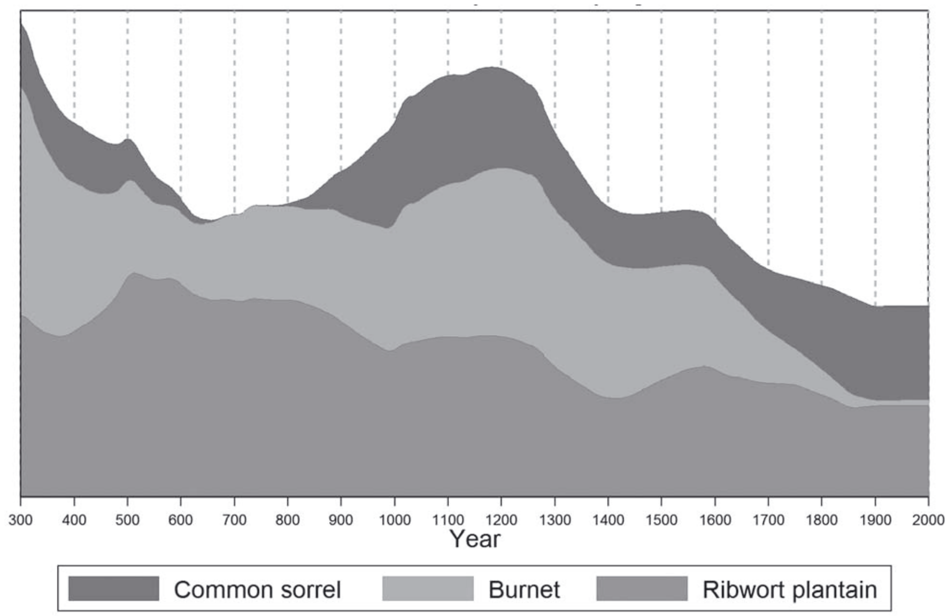


Figure 6. Central Greece: secondary anthropogenic indicators

Figure 7. Central Greece: steppic indicators

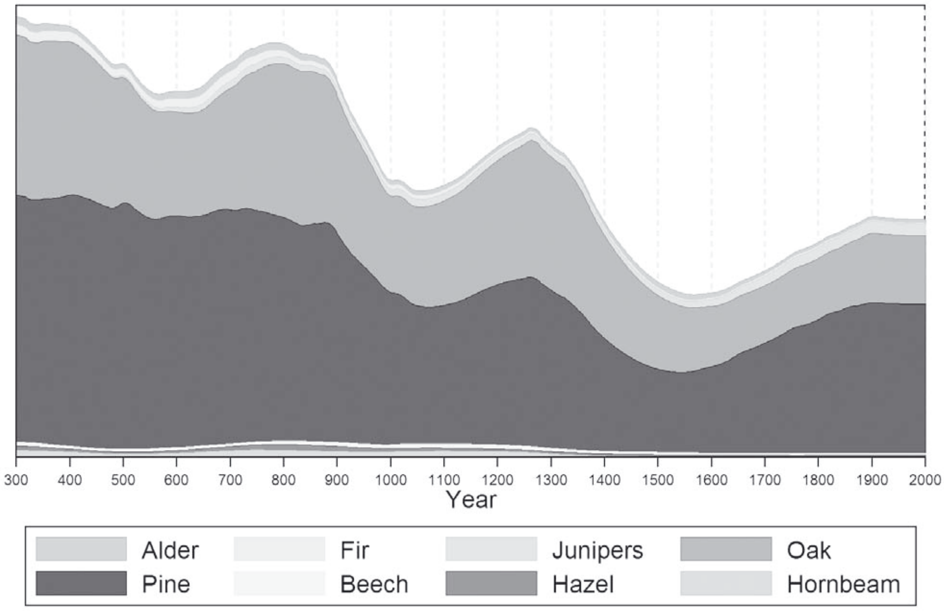


Figure 8. Central Greece: forest trees

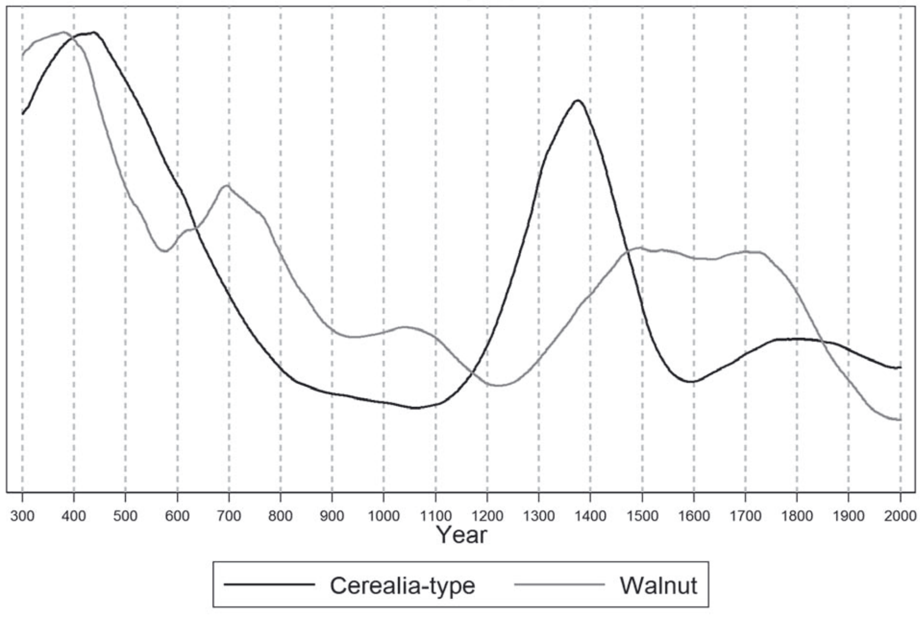


Figure 9. Macedonian highlands: anthropogenic indicators

Figure 10. Macedonian highlands: secondary anthropogenic indicators

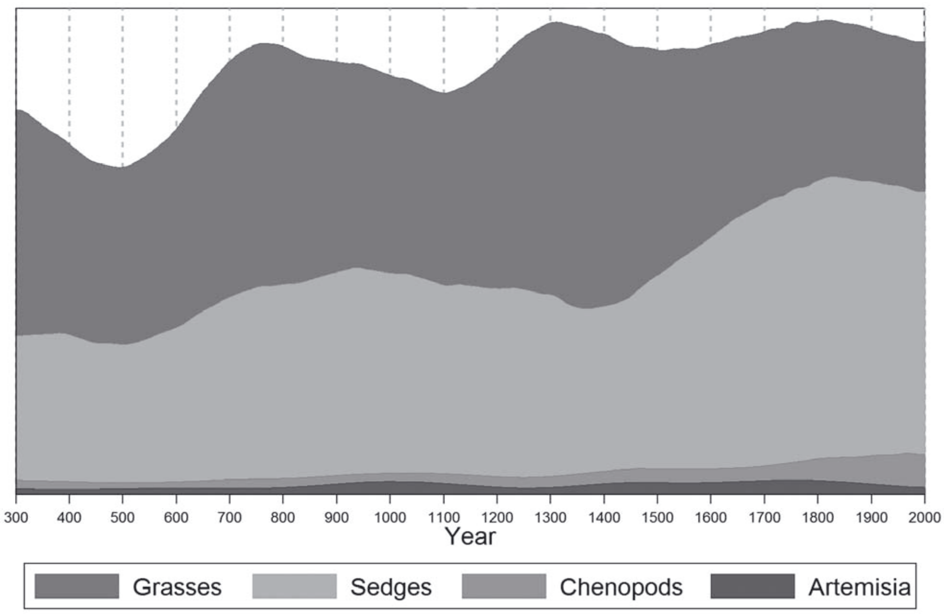


Figure 11. Macedonian highlands: steppic indicators

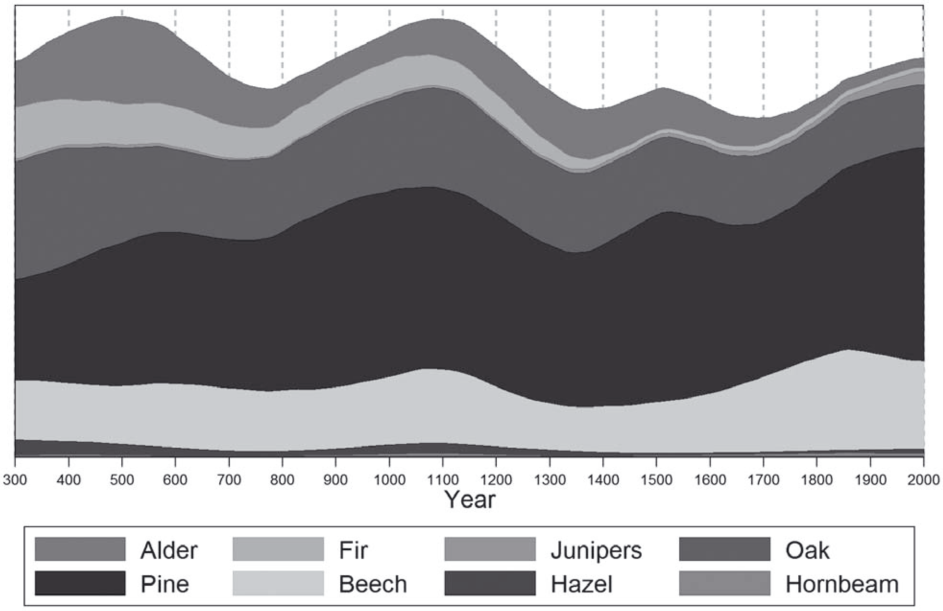


Figure 12. Macedonian highlands: forest trees

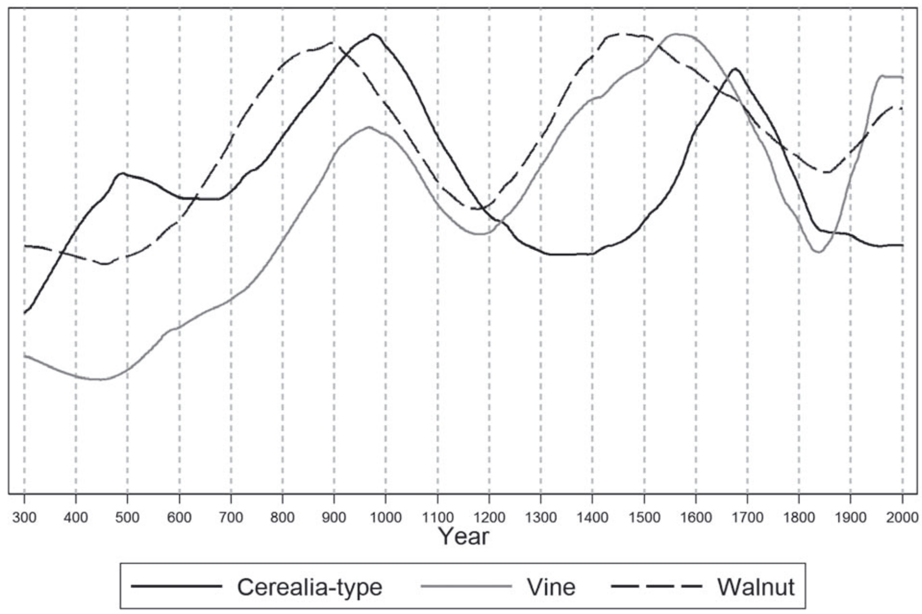


Figure 13. Western Bulgaria: anthropogenic indicators

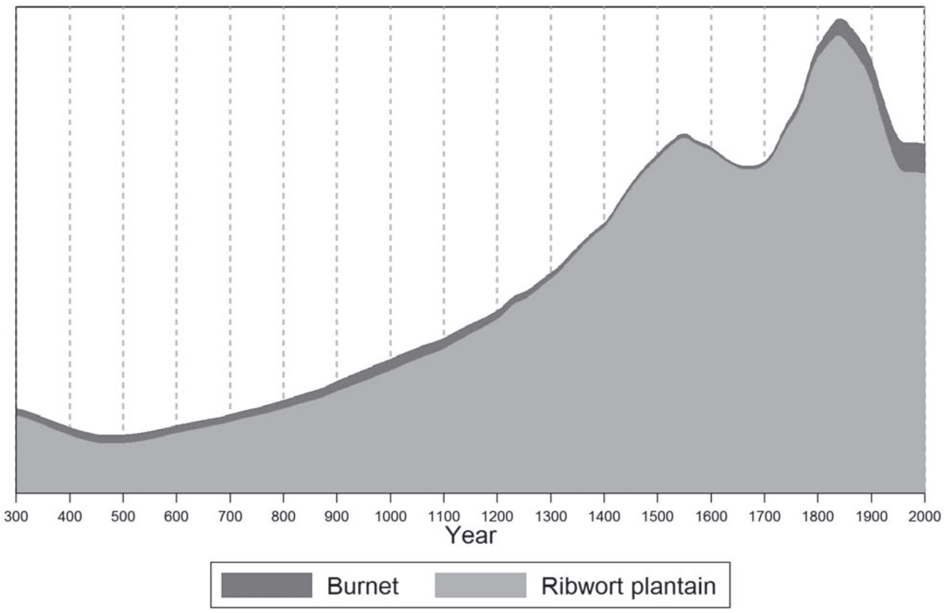


Figure 14. Western Bulgaria: secondary anthropogenic indicators

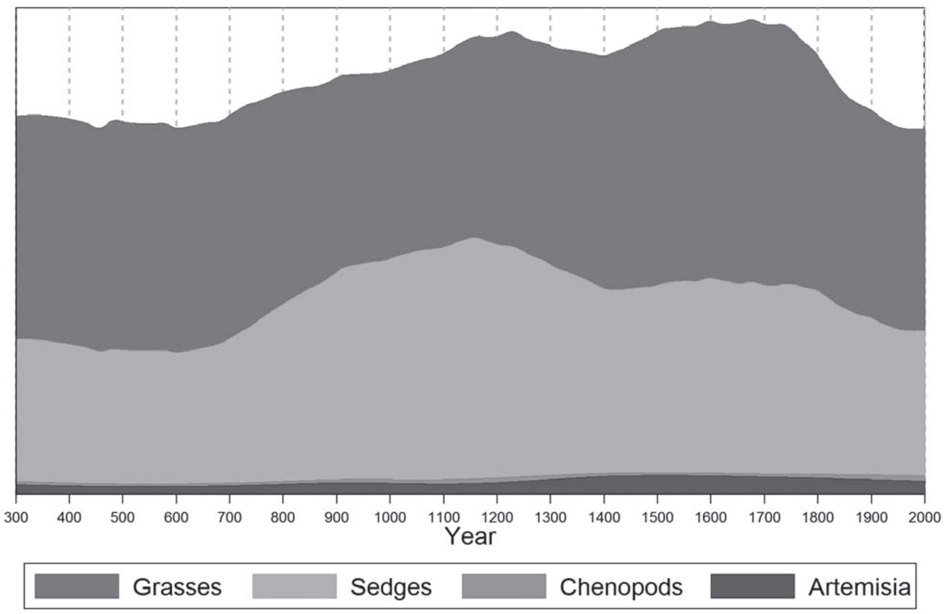


Figure 15. Western Bulgaria: steppic vegetation

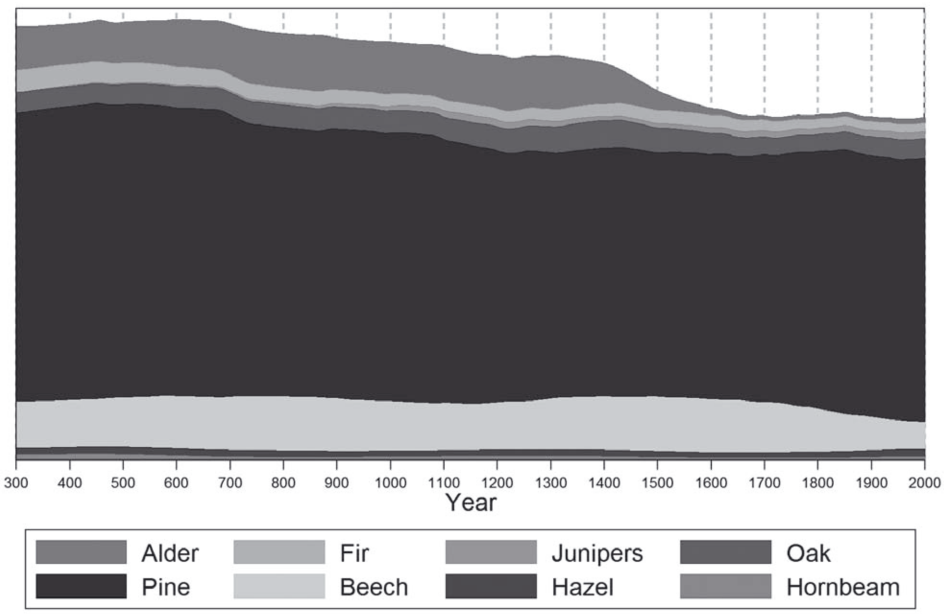


Figure 16. Western Bulgaria: forest trees

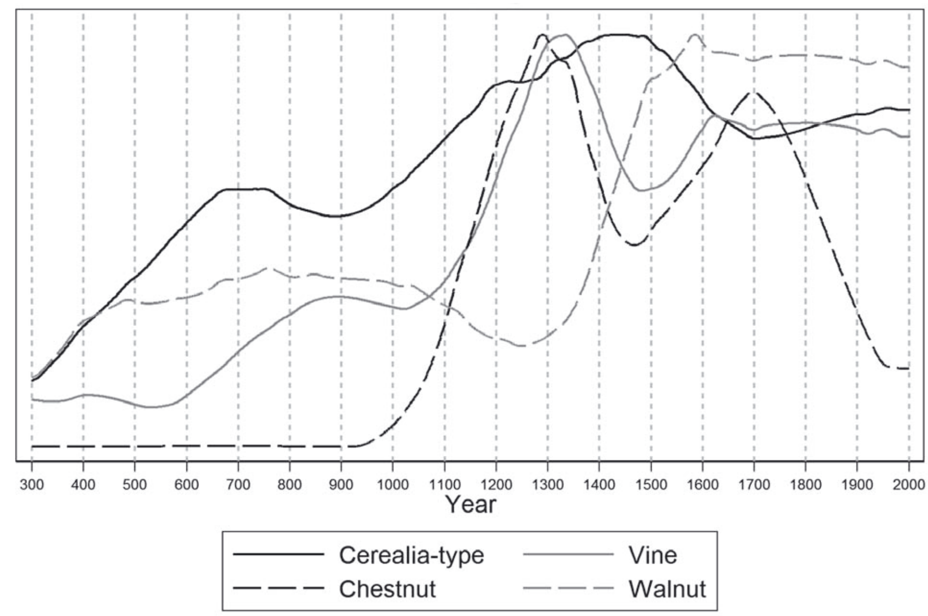


Figure 17. Eastern Bulgaria: anthropogenic indicators

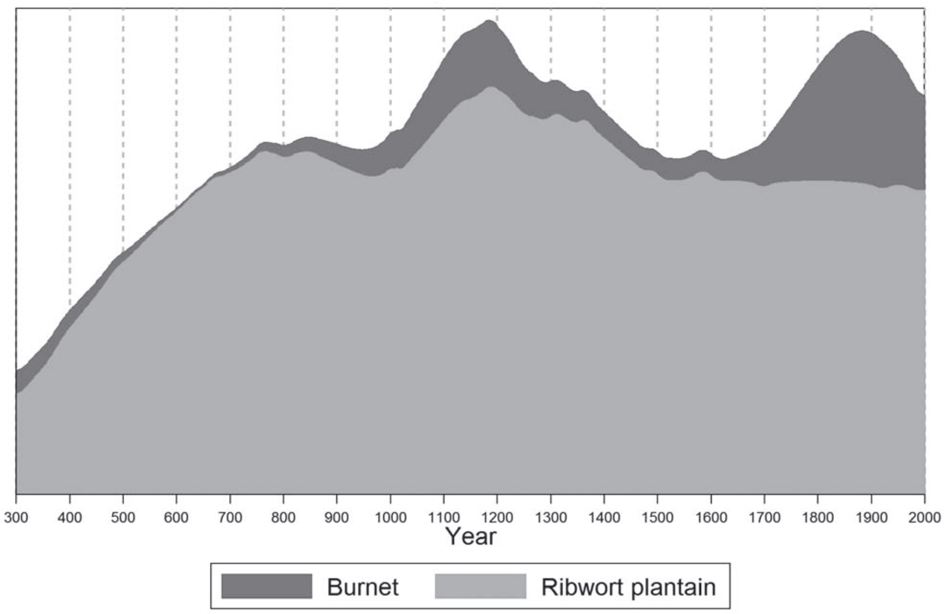


Figure 18. Eastern Bulgaria: secondary anthropogenic indicators

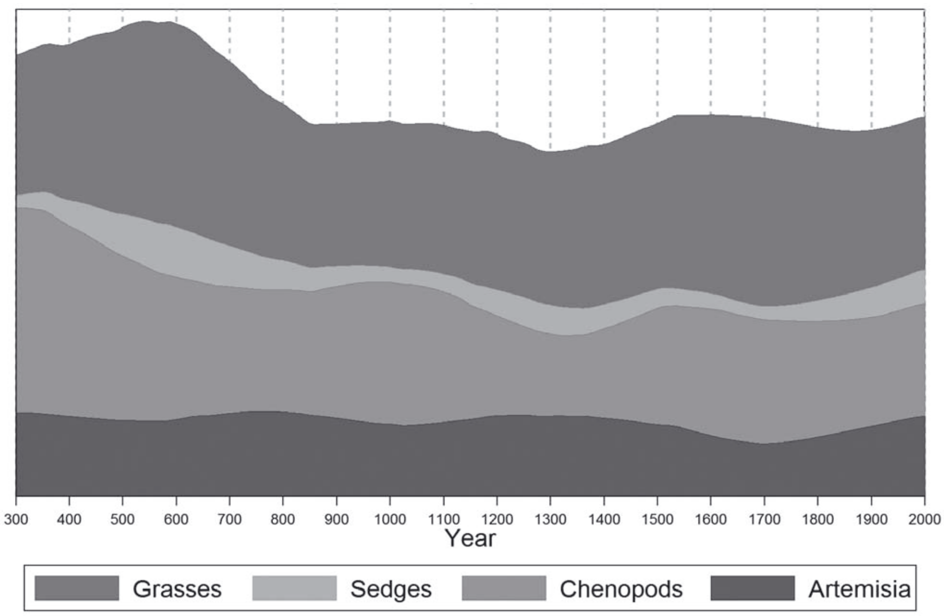


Figure 19. Eastern Bulgaria: steppic indicators

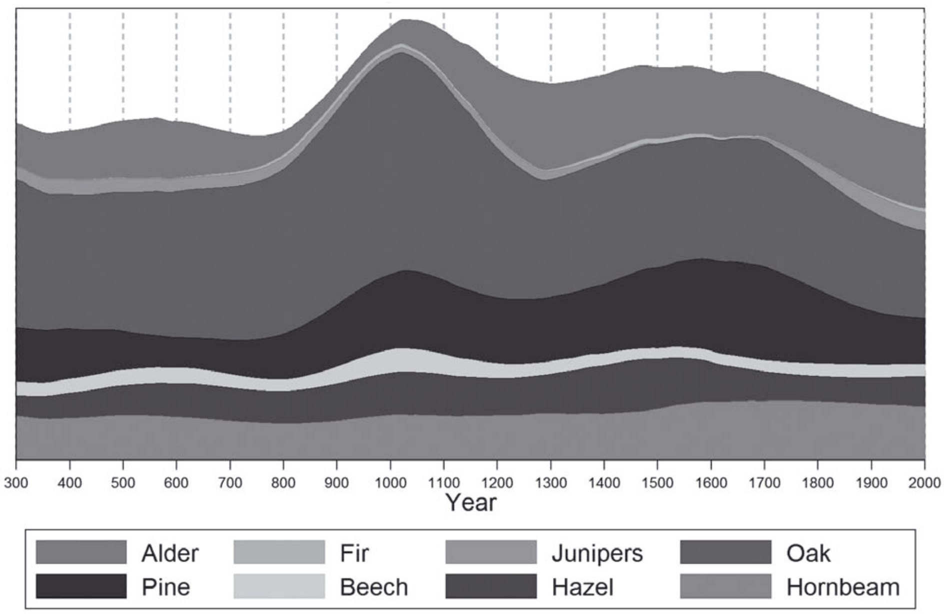


Figure 20. Eastern Bulgaria: forest trees

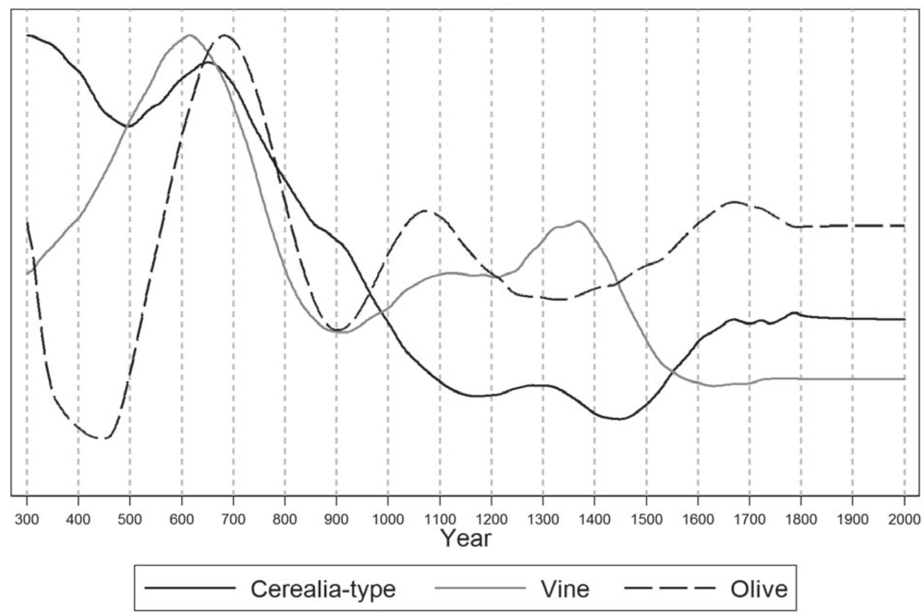


Figure 21. Eastern Bithynia: anthropogenic indicators

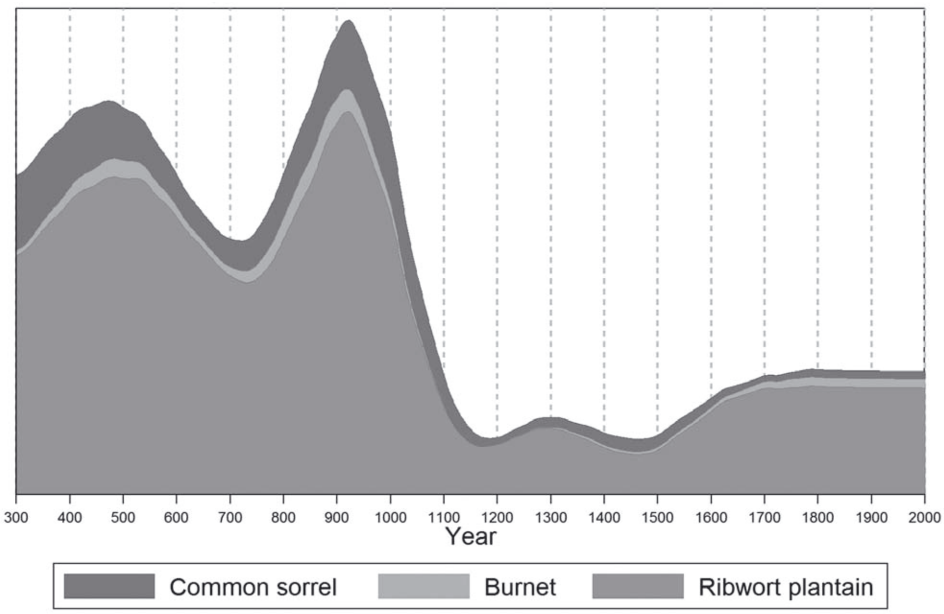


Figure 22. Eastern Bithynia: secondary anthropogenic indicators

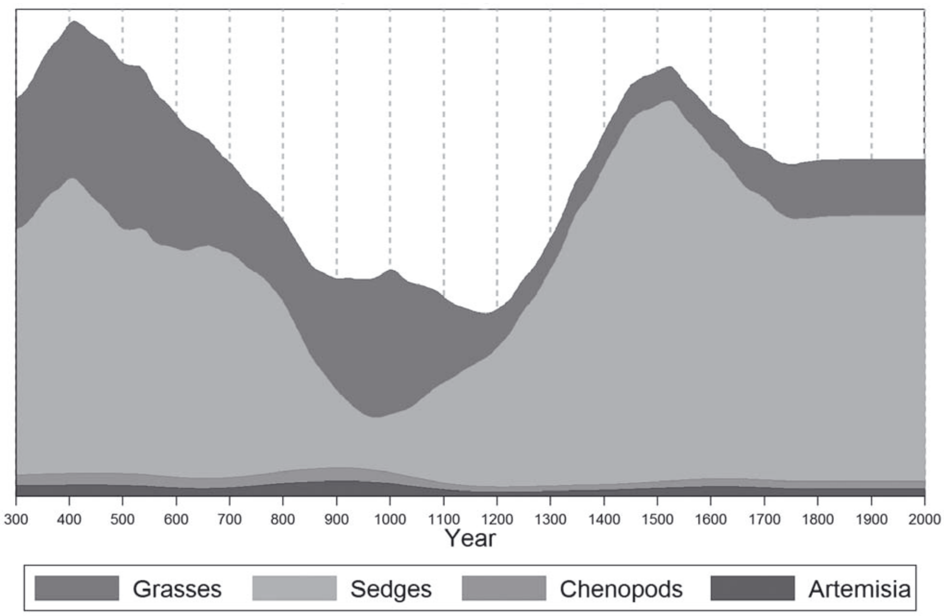


Figure 23. Eastern Bithynia: steppic indicators

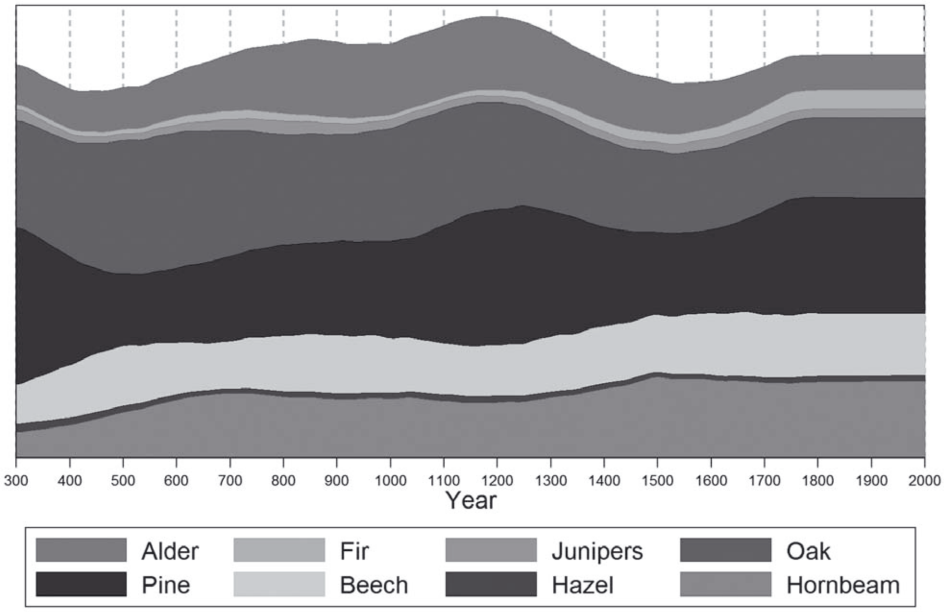


Figure 24. Eastern Bithynia: forest trees

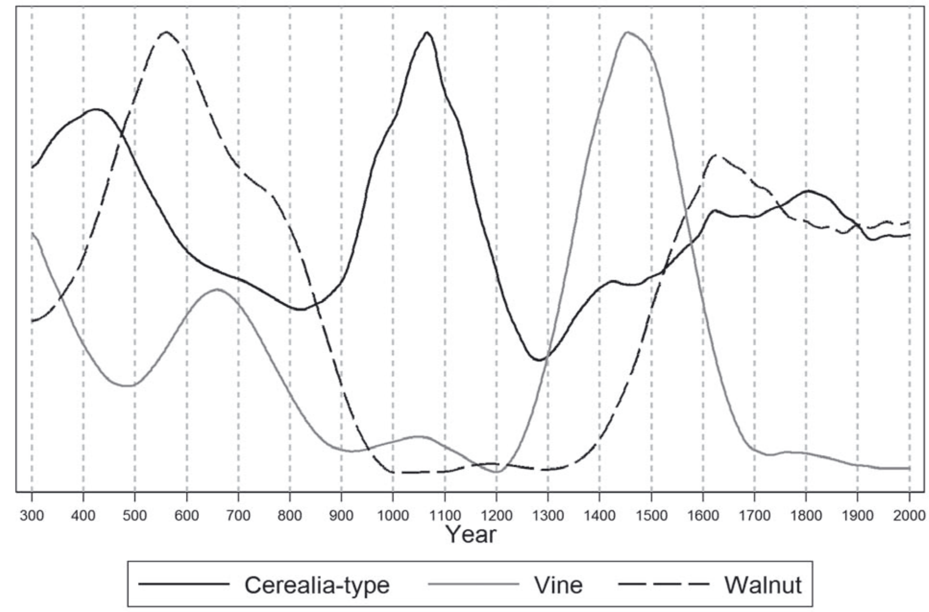
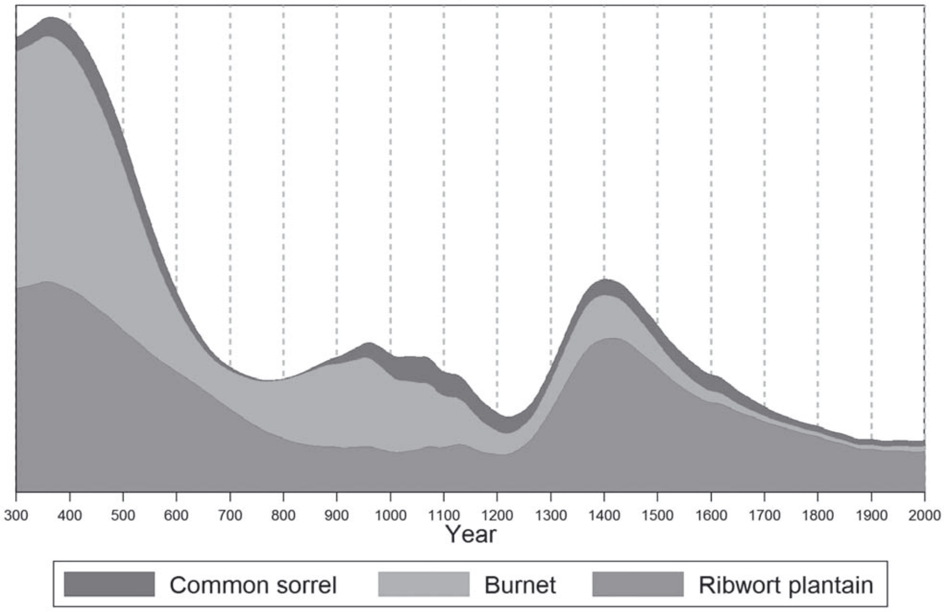


Figure 25. Inland Pontus: anthropogenic indicators



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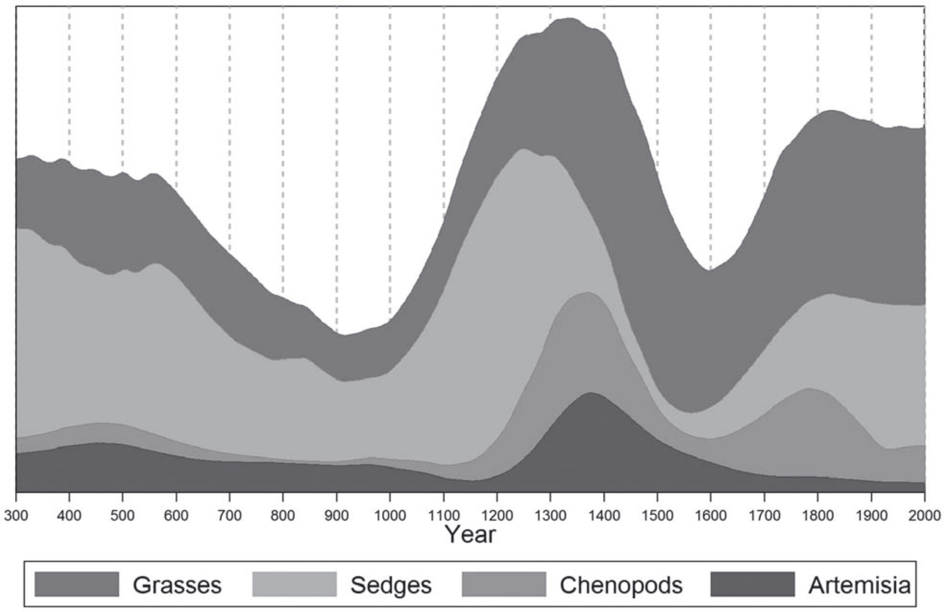

Figure 27. Inland Pontus: steppic indicators

Figure 28. Inland Pontus: forest trees

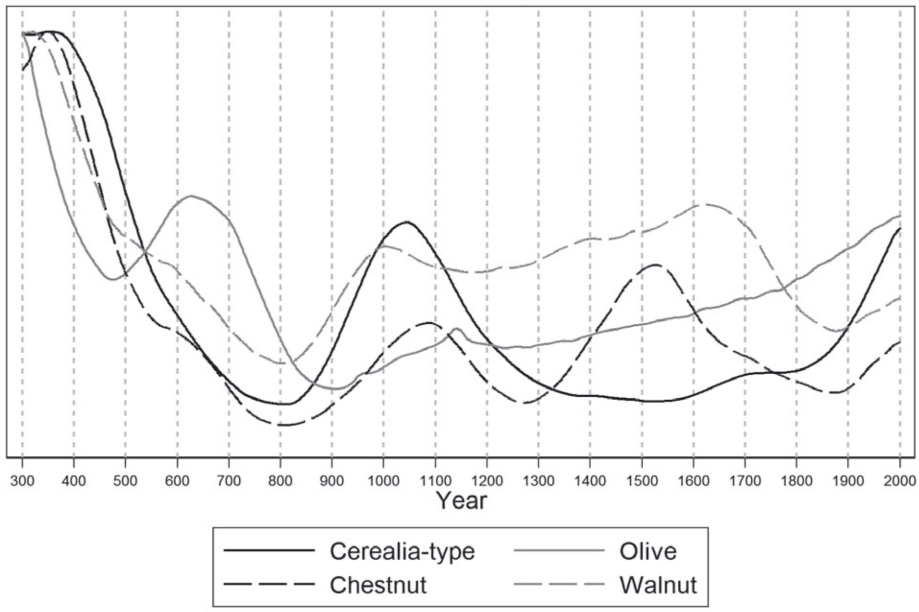

Figure 29. South-Western Anatolia: anthropogenic indicators

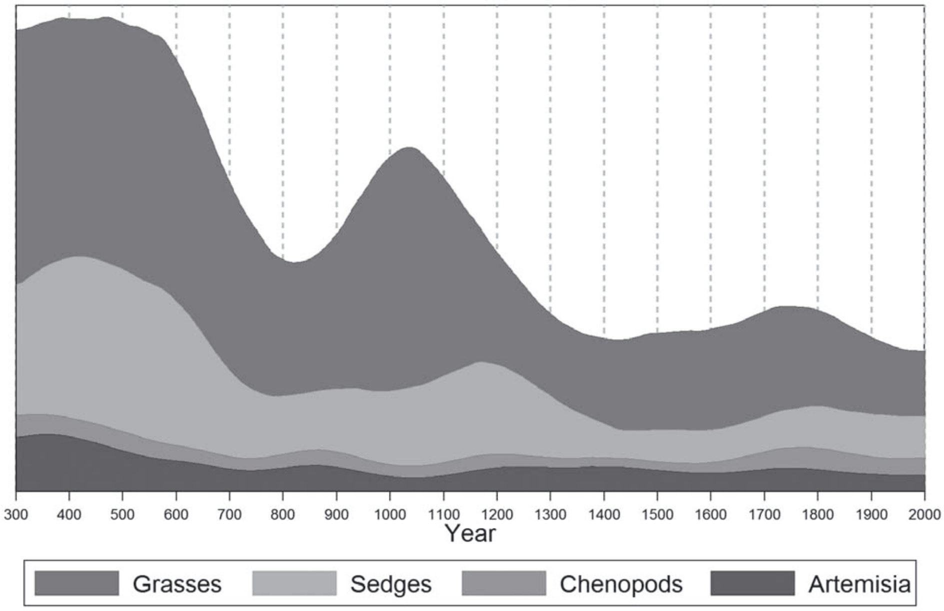

Figure 30. South-Western Anatolia: secondary anthropogenic indicators

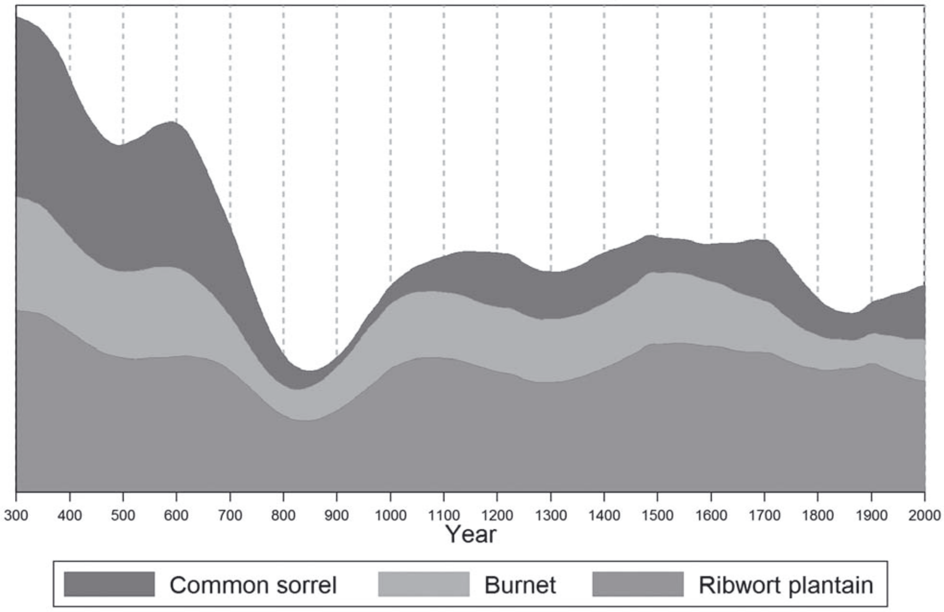

Figure 31. South-Western Anatolia: steppic indicators

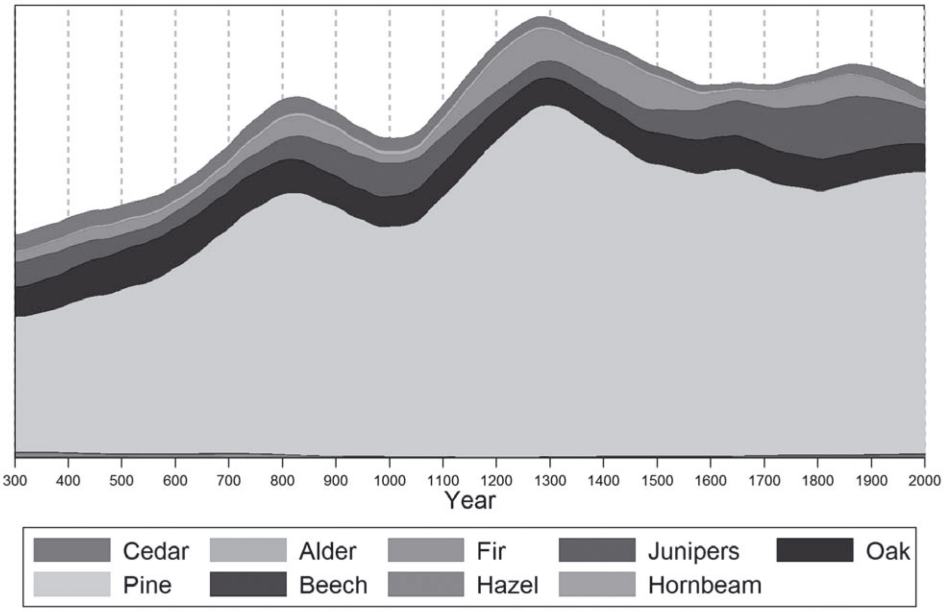

Figure 32. South-Western Anatolia: forest trees