



## “Cui Bono?” An Agricultural Turning Point in the Roman Provinces Upper Germania and Raetia

Manfred Rösch<sup>1,2</sup>, Elena Marinova<sup>2\*</sup>, Barbara Zach<sup>3</sup>

<sup>1</sup>Institut für Ur- und Frühgeschichte und Vorderasiatische Archäologie, Universität Heidelberg, Sandgasse 7, 69117 Heidelberg, Germany

<sup>2</sup>Laboratory for Archaeobotany, Baden-Württemberg State Office for Cultural Heritage, Fischersteig 9, 78343 Gaienhofen-Hemmenhofen, Germany

<sup>3</sup>Archäobotanik Labor Zach, Weidachring 4, 86975 Bernbeuren, Germany

### ARTICLE INFO

#### Article history:

Received: 11<sup>th</sup> July 2023

Accepted: 11<sup>th</sup> June 2024

DOI: <http://dx.doi.org/10.24916/iansa.2024.2.2>

#### Key words:

agricultural intensification  
archaeobotany  
pollen analysis  
plant macrofossils  
southwestern Germany

### ABSTRACT

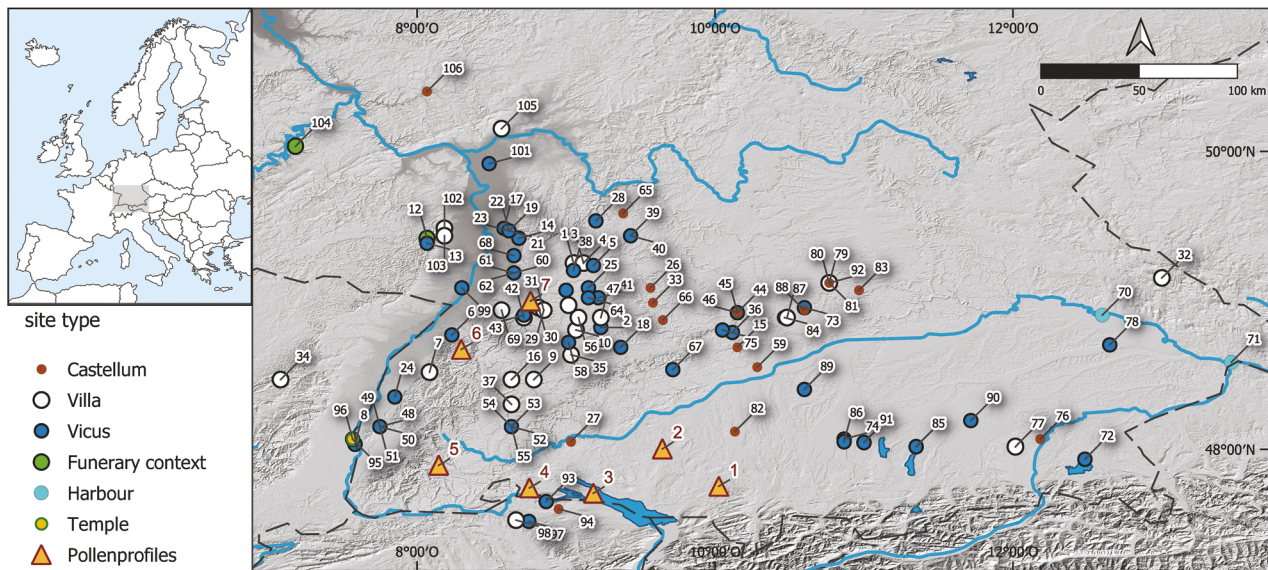
The history of agricultural innovation, intensification and the associated diversity of land use and plant food consumption in the Roman provinces of Upper Germania and Raetia was investigated using charred plant macrofossils (on-site data) and pollen assemblages (off-site data). A presence/absence data set compiled from major published data (n=106) allowed to assess the diversity of food plants according to site types. Highest diversity occurred at small *vici* (rural villages), reflecting the diversity of features studied, but also the diversity of activities typical for this site type. Generally, the larger, urbanised or military sites, such as forts and large *vici* (country towns), show higher plant food diversity compared to the smaller, rural sites such as *villae rusticae*. This difference is based mainly on the diversity of fruits, vegetables and spices consumed. To put the results in a broader chronological context, the feature-based ubiquity of charred finds of six taxa, as indicators of less intensive agriculture (*i.e.* low-intensity tillage, longer fallow period, smaller field sizes) were evaluated. This dataset obtained from 248 archaeological sites covering the period from Bronze Age to Middle Ages, showed the strongest decrease of perennial arable weeds during the Roman period pointing to a possible shortening of fallow periods and deeper tillage than before. The pollen records (n=7) indicate a decreasing importance of wood pasture and ruderals during the Roman period compared to the preceding and following periods. The studied archaeobotanical evidence indicates a clear turning point in food culture and land use in the area during the Roman period.

### 1. Introduction

Roman authors dealing with agriculture, such as Cato the Elder, Columella, both Plinius, Varro, and Palladius, describe the sophisticated methods that Romans practised in agriculture and animal husbandry (Körber-Grohne, 1979; Drexhage *et al.*, 2002; Kloft, 2005; Rodgers, 2010; Paffgen, 2014). Direct and locally specific evidence related to the traces of this agriculture, consumption of plants and associated rituals can be obtained from archaeobotanical research that considers plant remains found at or linked to excavations of Roman sites. The archaeobotanical evidence for the introduction of Roman agriculture in the northern provinces confirms the knowledge from written sources, but

also provides a much more detailed and differentiated picture. The land use system introduced by the Romans resulted in a considerable expansion of horticulture and arboriculture (Vandorpe, 2010; Kreuz and Wiethold, 2010; Livarda, 2011; Krebs *et al.*, 2022), including vineyards (Rösch, 2016). This shift in land use and associated agricultural practices like the cultivation of a variety of fruit trees, vegetables, and garden herbs would also have the effect of increasing human impact on the landscape by including new cultivated areas. For example, the areas used for arboriculture were usually newly acquired and spatially different than those for annual crop cultivation (Marzano, 2022). In south-west Germany, these were areas which were too steep for ploughing, or had too heavy soils, but which were still suitable for orchards for which no tillage is necessary (Arnold and Rösch, 2011; Rösch, 2018). Moreover, the emphasis of the Roman agricultural

\*Corresponding author. E-mail: [elena.marinova-wolff@rps.bwl.de](mailto:elena.marinova-wolff@rps.bwl.de)



**Figure 1.** Map with archaeological sites marked by circles (numeration given in Table 1) and pollen sites marked by a red bordered triangle: 1. Großer Ursee (Rösch *et al.*, 2021), 2. Zellsee (Rösch and Marinova, 2020) 3. Mainau (Rösch and Wick, 2018), 4. Hartsee (Rösch and Lechterbeck, in press), 5. Titisee (Knopf *et al.*, 2019), 6. Herrenwieser See (Rösch and Tserendorj, 2011), 7. Aalkistensee (Rösch *et al.*, 2018))

economy towards surpluses would have increased the pressure to enhance productivity on the existing and newly cultivated areas. As many agricultural activities result in soil depletion and nutrient loss, the maintenance of soil fertility is an important element of cultivation practices – including those in Roman times. The regular alternation between cropping and fallowing is one of the main approaches to sustain soil fertility using organic matter coming mainly from humus regeneration (Schulze, 2014). Restoration of the topsoil humus by using fallow periods is the main principle of shifting cultivation systems practised in Central Europe since prehistory (Dreslerová *et al.*, 2021). In the study area, previous research has recognised such practices, for example, the Neolithic slash-and-burn agriculture (Rösch *et al.*, 2017), as well as the field-grass-economy practised in the region since the Bronze Age (Tserendorj *et al.*, 2021). The longer the fallow period and the less intensive the tillage, the more perennials can grow. Before modern times, grassland or “pasture” vegetation occurred mostly on fallow land (Hejcman *et al.*, 2013), being favoured by regular shifts between crop cultivation and fallow used as pasture, and by less intensive tillage (Poschold, 2017). A decrease in perennials would indicate the transition to a field system involving more intensive ploughing and/or shorter fallow periods. The more intensive the ploughing is, by the use of a mouldboard plough instead of an ard (scratch plough) for example, the deeper is the resulting interference of the field. Their efforts can be described as elements of an agricultural intensification in terms of an increase in both energy applied and harvest collected from a unit of land, *i.e.* the amount of agricultural production per unit of inputs (Park and Allaby, 2017). Without long fallow periods manuring is necessary to maintain the fertility of the soil and according to bioarchaeological evidence at some of the Roman provinces

or within different regions manuring was applied, but additionally other measures such as the selection of crops for specific soil types and larger cultivation areas would have played a role (Aguilera *et al.*, 2017; Lodwick *et al.*, 2021). The biology of crop weeds, including species which today are considered as ruderals or pasture elements, but most probably were part of the arable-field flora in the past, can provide detailed information on the cultivation techniques and arable field conditions encountered (van der Veen, 1992; Bogaard *et al.*, 2016).

The newly cultivated and imported plants introduced during the Roman period, having every day or luxury functions, as well as ritual purposes (Bakels *et al.*, 1997; Jacomet, 2003; Zach, 2002), added a significant diversity to the food cultures of the Romanised areas north of the Alps (Kreuz, 2005; van der Veen *et al.*, 2008; Jacomet, 2014; Wiethold, 2012). Moreover, the diversity of Roman site types and, related with them, structures, might also bear traces of the diversity of plant food consumption (*sensu* van der Veen, 2007), which shall be traceable by the archaeobotanical record from those site types. Thus, with the increasing number of detailed, context related archaeobotanical studies from the northern Roman provinces Upper Germania and Raetia, a closer examination of site-specific food consumption pattern is also possible.

Therefore, the current paper considers the detailed and regionally-specific evidence on past crop use and cultivation as well as some associated land use practices such as tillage intensity, possible manuring, and fallow duration. Such practices are inferred by the archaeobotanical finds from cultural layers (on-site) and by pollen from nearby sediment archives (off-site) from the region corresponding to the Roman provinces of Upper Germania and Raetia, *i.e.* southern Germany, Switzerland, and eastern France (Figure 1). The length of the Roman period in this area differs considerably, getting shorter as we move from

south-west to north-east. Gallia was colonised by Caesar rather early (ca. 58–51 BC), while the region east of the Neckar was taken by Roman rule two centuries later, when the last Limes of Upper Germania and Raetia were built (between 120 and 160 AD). These north-eastern areas were however, lost a century later when the Romans retreated behind the Rhine and Danube. The rest remained part of the Roman Empire until its end in the late 5<sup>th</sup> century AD.

The main focus of this paper is on the consumed plant food as well as land use, in terms of selected aspects of cultivation techniques and farming strategies during the Roman age in Upper Germania and Raetia, as reflected in the archaeobotanical evidence. By analysing the available macrobotanical and palynological data sets, we aim to evaluate archaeobotanical indicators that point to changes in the intensity of plant production and land use during the Roman period compared to preceding and subsequent periods, as well as site-type-specific patterns of food plants introduced by the Romans. The overall goal was, therefore, to gain a better understanding of the impact on the landscape and food culture caused by the major economic change that was introduced by the Romans within the study regions.

## 2. Material and methods

### 2.1 On-site data

On-site data analysis included archaeobotanical evidence from archaeological sites, available in the database of the

Laboratory for Archaeobotany of the Baden-Württemberg State Office for Cultural Heritage, organised in the software ArboDat (Kreuz and Schäfer, 2002). To cover the provinces Germania superior and Raetia, additional published archaeobotanical data from the German provinces Bavaria, Rhineland-Pfalz, and Hesse as well from Switzerland and Eastern France, were included. This second group of data was not always published as fully quantified assemblages. Therefore, only the presence/absence data could be reliably used for the total of 106 sites from the study region (Table 1 and Figure 1). The evidence was arranged according to site type: *castellum*, *vicus* in urban context, *vicus* in rural context, *villa rustica*, burial context and temple. Additionally, not only the site type, but also information (when available from available essential metadata), such as the number of studied features, samples and sediment volume processed was collected. This information is considered as the basic characteristic of the archaeobotanical assemblages and helpful in illustrating how representative they are. The collected data set is heterogenous, but due to the large number of sites considered it is suitable for a more or less reliable estimation of the diversity (Figure 2) of food plants and to infer their ubiquity (*i.e.* relative importance) per site type (Figure 3). Moreover, the features-based ubiquity (Figure 4) of charred plant macro-remains that indicate less intensive tillage (and longer fallow) was calculated from the Baden-Württemberg dataset (based on 248 sites in total) to estimate the diachronic importance of fallow land. We focused on today's typical grassland species that were also part of the

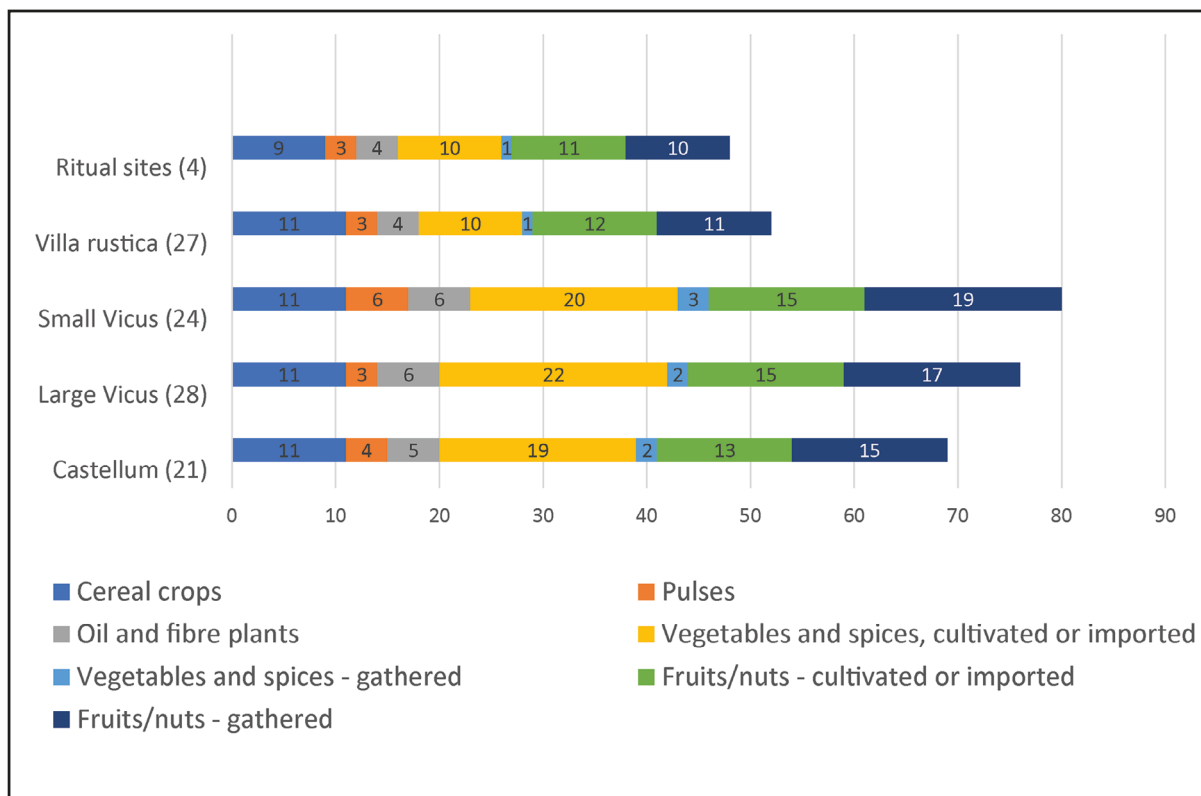


Figure 2. Crop diversity per site (n=106) types.

**Table 1.** Main parameters of the Roman Age data sets considered in the current paper.

No.	Site	Latitude	Longitude	Altitude (m)	Site Type	Size	Feature type	Number of features	Number of samples	Volume	Waterlogged	Features	Reference
<b>Baden-Württemberg</b>													
1	Babstadt	49°15' N	9°03' E	248	<i>Villa</i>		well, granary	2	19	72.15			Reichle, 2002
2	Bad Cannstatt- Stuttgart	48°49' N	9°14' E	243	<i>Vicus</i>	large	cellar	4	10	12.36	w		Marinova <i>et al.</i> , 2019
3	Bad Rappenau	49°15' N	9°07' E	227	<i>Villa</i>		granary	3	6	8.95			Rösch, 2009b
4	Bad Rappenau	49°15' N	9°07' E	227	<i>Villa</i>		granary	1	1				Reichle, 2002
5	Bad Wimpfen im Tal	49°14' N	9°11' E	148	<i>Vicus</i>		well	38	38		w		Fröschle, in print
6	Baden-Baden	48°46' N	8°14' E	161	<i>Vicus</i>	large	divers	21	42		w		Stika, 1996
7	Bondorf	48°31' N	8°50' E	458	<i>Villa</i>		cultural layer	2	2				Körber-Grohne and Piening, 1979
8	Breisach	48°02' N	7°35' E	191	<i>Vicus</i>	large	pit	1	1				Lab.Arbo.unpub.
9	Eutingen im Gäu, Rohrdorf	48°28' N	8°47' E	479	<i>Villa</i>		pit	1	1	2.5			Lab.Arbo.unpub.
10	Gerlingen	48°48' N	9°04' E	333	<i>Villa</i>		cellar	12					Lab.Arbo.unpub.
11	Güglingen	49°04' N	9°00' E	205	<i>Vicus</i>	small	divers	19	36	101.9	w		Rösch, 2005
12	Heidelberg, Neuenheimer Feld	49°25' N	8°40' E	108	Graves		graves	61	61	0.24			Märkle and Fischer, 2009
13	Heidelberg-Kirchheim	49°23' N	8°40' E	109	<i>Vicus</i>	large	divers	4	4	15.4			Lab.Arbo.unpub.
14	Heidelberg-Neuenheim	49°25' N	8°41' E	112	<i>Vicus</i>	large	well, pits	4	16	18.21	w		Rösch, 2012
15	Heidenheim	48°41' N	10°09' E	491	Fort		pit	1	1				Lab.Arbo.unpub.
16	Horb-Altheim	48°28' N	8°38' E	557	<i>Villa</i>		pits	1	1				Lab.Arbo.unpub.
17	Ilvesheim	49°29' N	8°35' E	97	<i>Vicus</i>	small?	pits, ditches	2	7	130.43			Lab.Arbo.unpub.
18	Köngen	48°41' N	9°22' E	331	<i>Vicus</i>	small?	well				w		S. Maier, 1988
19	Ladenburg	49°28' N	8°37' E	105	Fort		well, pits	4	10	16.47	w		Lab.Arbo.unpub.
20	Ladenburg	49°28' N	8°37' E	105	<i>Vicus</i>	large	pits, cultural layer	2	5	25.05			Lab.Arbo.unpub.
21	Ladenburg	49°28' N	8°37' E	105	<i>Vicus</i>	large	well, grave	3	4	19.26	w		Lab.Arbo.unpub.
22	Ladenburg	49°28' N	8°37' E	105	<i>Vicus</i>	large	well	2	2	21.5	w		Lab.Arbo.unpub.
23	Ladenburg	49°28' N	8°37' E	105	<i>Vicus</i>	large	latrine	6	7	6.81	w		U. Maier
24	Lahr-Dinglingen	48°21' N	7°51' E	159	<i>Vicus</i>	small	wells, pits	14	14	19.03	w		Rösch, 1995, 2018
25	Lauffen	49°05' N	9°09' E	175	<i>Villa</i>		cellar	1	1				Piening 1982
26	Mainhardt	49°05' N	9°34' E	484	Fort/ <i>Vicus</i>	small	well	1	10	2.5	w		Körber-Grohne and Rösch, 1988
27	Mengen	48°03' N	9°20' E	560	Fort		pits	1	2				Rösch, 2009a

**Table 1.** Main parameters of the Roman Age data sets considered in the current paper. (Continuation)

No.	Site	Latitude	Longitude	Altitude (m)	Site Type	Size	Feature type	Number of features	Number of samples	Volume	Waterlogged	Features	Reference
28	Mudau	49°32' N	9°12' E	451	<i>Vicus</i>	small	pits, cultural layer	1	1	5.5		Lab.Arbo.unpub.	
29	Mühlacker-Dürrenz	48°56' N	8°51' E	222	<i>Vicus</i>	small	graves, pits, sunken huts	5	21	16		Rösch, 2013	
30	Mühlacker-Enzberg	48°57' N	8°49' E	228	<i>Villa</i>		pits and others	8	8	0.39		Hugonot <i>et al.</i> , 1991	
31	Mühlacker-Lomersheim	48°56' N	8°51' E	219	<i>Villa</i>		cellar	7	7		w	Stika, 1996	
32	Mundelsheim	49°00' N	9°13' E	202	<i>Villa</i>		well	3	3		w	Rösch, 1989, Lab.Arbo.unpub.	
33	Murrhardt	48°59' N	9°35' E	288	Fort/ <i>Vicus</i>		well	4	4	4.17		Lab.Arbo.unpub.	
34	Neuried-Müllen	48°28' N	7°50' E	146	<i>Villa</i>		well	1	1			Stika, 1996	
35	Nürtingen	48°38' N	9°20' E	273	<i>Villa</i>		cellar	6	8	4.92		Piening, 1982	
36	Oberkochen	48°47' N	10°07' E	487	<i>Vicus</i>		cellar	1	4			Lab.Arbo.unpub.	
37	Oberndorf-Bochingen	48°18' N	8°38' E	571	<i>Villa</i>	large	divers	1	37	9.25	w	Fröschle, 1994	
38	Öhringen	49°12' N	9°30' E	230	<i>Vicus</i>		SoBefu	1	5	7.65		Lab.Arbo.unpub.	
39	Osterburken	49°26' N	9°26' E	266	Temple		well	4	4	9.6		Lab.Arbo.unpub.	
40	Osterburken	49°26' N	9°26' E	266	<i>Vicus</i>		cultural layer	7	39	41.93	w	Fietz, 1961	
41	Ottmarsheim	49°01' N	9°13' E	327	<i>Vicus</i>		pits	13	12		w	Stika, 1996	
42	Pforzheim, Städt. Krankenhaus	48°53' N	8°43' E	251	<i>Villa</i>	large	wells, pits	11	12			Lab.Arbo.unpub.	
43	Pforzheim-Kappelhof	48°54' N	8°43' E	251	<i>Vicus</i>	small	well and others	8	12	18.3	w	Piening, 1982	
44	Rainau-Buch	48°55' N	10°09' E	465	Fort/ <i>Vicus</i>	small	well	4	5	37.1	w	Lab.Arbo.unpub.	
45	Rainau-Buch	48°55' N	10°09' E	465	<i>Vicus</i>	small	pits, cellar	1	1			Lab.Arbo.unpub.	
46	Rainau-Buch	48°55' N	10°09' E	465	Fort/ <i>Vicus</i>		cellar	8	12		w	Lab.Arbo.unpub.	
47	Remseck-Aldingen	48°53' N	9°14' E	272	<i>Villa</i>	small	latrine	4	5			Lab.Arbo.unpub.	
48	Riegel	48°09' N	7°45' E	185	<i>Vicus</i>		pit, latrine	4	4			Lab.Arbo.unpub.	
49	Riegel	48°09' N	7°45' E	185	<i>Vicus</i>	small?	well	1	4		w	Stika, 1996	
50	Riegel	48°09' N	7°45' E	185	<i>Vicus</i>	large	well	1	4		w	Baas, 1974	
51	Riegel, Fronhofbuck	48°09' N	7°45' E	185	<i>Vicus</i>	large	well	1	1			Stika, 1996	
52	Rottweil	48°09' N	8°38' E	590	<i>Vicus</i>	large	well	4	4		w	Stika, 1996	
53	Rottweil, Hochmauren	48°09' N	8°38' E	590	<i>Vicus</i>	large	pit	1	1			Stika, 1996	
54	Rottweil, Steinwandel	48°09' N	8°38' E	590	<i>Vicus</i>	large	well	4	4		w	Stika, 1996	



Table 1. Main parameters of the Roman Age data sets considered in the current paper. (Continuation)

No.	Site	Latitude	Longitude	Altitude (m)	Site Type	Size	Feature type	Number of features	Number of samples	Volume	Waterlogged features	Reference
55	Rottweil, Kapellenösch	48°09' N	8°38' E	590	<i>Vicus</i>	large	bustum	1	1	1		Lab.Arbo.unpub.
56	Schwieberdingen	48°53' N	9°05' E	275	<i>Villa</i>		pit	6	7	30.22		Lab.Arbo.unpub.
57	Sersheim	48°58' N	9°01' E	215	<i>Villa</i>		pit, cellar	1	1	0.76		Lab.Arbo.unpub.
58	Sindelfingen	48°43' N	9°01' E	433	<i>Vicus</i>	small	well	10	12	11.67	w	Stika, 1996
59	Sontheim/Brenz	48°33' N	10°17' E	446	Fort		well	1	1		w	Rösch, 1991
60	Stettfeld, Mühberg	49°11' N	8°39' E	119	<i>Vicus</i>	large	well	21	39	199	w	Stika, 1996
61	Stettfeld	49°11' N	8°39' E	119	<i>Vicus</i>	large	well, kiln	1	1			Lab.Arbo.unpub.
62	Stettfeld, Marcellusplatz	49°11' N	8°39' E	119	<i>Vicus</i>	large	cellar	1	1			Stika, 1996
63	Stettfeld, Talstr.	49°11' N	8°39' E	119	<i>Vicus</i>	large	well	3	3		w	Stika, 1996
64	Walheim	49°01' N	9°09' E	183	<i>Vicus</i>			10	10		w	Pföhler, 1990
65	Walldüren, Am Römerbad	49°35' N	9°23' E	400	Fort/ <i>Vicus</i>	small	cellar	4	15			Stika, 1996
66	Welzheim Ostkastell	48°52' N	9°39' E	495	Fort		wells, pits	20	36	140	w	Körber-Grohne <i>et al.</i> , 1983
67	Widderstall-Mittelbuchen	48°32' N	9°43' E	751	<i>Vicus</i>	small	cultural layer	1	1	0.12		Lab.Arbo.unpub.
68	Wiesloch	49°18' N	8°39' E	106	<i>Vicus</i>	large?	pits	1	1			Rösch, 1993
69	Wilferdingen	48°56' N	8°34' E	162	<i>Villa</i>		cultural layer	1	1	2100		Lab.Arbo.unpub.
<b>Bayern</b>												
70	Straubing-Azilburg	48°54' N	12°36' E	330	Port			169				Küster, 1995
71	Passau	48°35' N	13°28' E	300	Port			11				Küster, 1995
72	Seebuck	47°56' N	12°29' E	526	<i>Vicus</i>	large		8				Küster, 1995
73	Oettingen	48°57' N	10°36' E	419	<i>Vicus</i>	large		2				Küster, 1995
74	Oberndorf	48°40' N	10°52' E	407	<i>Vicus</i>	large		2				Küster, 1995
75	Großsorheim	48°48' N	10°30' E	447	<i>Vicus</i>	large		4				Küster, 1995
76	Künzing	48°40' N	13°05' E	310	Fort			47				Küster, 1995
77	Steinkirchen	48°01' N	12°01' E	493	<i>Villa</i>			1				Küster, 1995
78	Pilsting	48°42' N	12°39' E	341	<i>Vicus</i>	small		5				Küster, 1995
79	Weißenburg-Gunzenhausen	49°07' N	10°46' E	421	<i>Villa</i>			18				Küster, 1995
80	Weißenburg-Gunzenhausen	49°07' N	10°46' E	421	Fort			4				Küster, 1995
81	Weißenburg-Gunzenhausen	49°07' N	10°46' E	421	Fort/ <i>Vicus</i>	large		8				Küster, 1995

**Table 1.** Main parameters of the Roman Age data sets considered in the current paper. (Continuation)

No.	Site	Latitude	Longitude	Altitude (m)	Site Type	Size	Feature type	Number of features	Number of samples	Volume	Waterlogged features	Reference
82	Kellmünz	48°07' N	10°08' E	522	Fort			2				Küster, 1995
83	Ellingen	49°04' N	10°58' E	396	Fort		wells	12		w		Frank and Stika, 1988
84	Münchsmünster - Nördlingen (BaWü), Ehringen 2008	48°53' N	10°28' E	433	Fort		?	4				Zach unpubl.
85	Aubing	48°10' N	11°21' E	530	Villa		?	10				Zach unpubl.
86	Langweid	48°30' N	10°52' E	450	Fort		occupation layer	15				Zach unpubl.
87	Ehringen-Wallerstein	48°53' N	10°29' E	431	Villa		well	4		w		Steeger unpubl.
88	Munningen	48°56' N	10°36' E	418	Fort		wells, pit	43		w		Gerhard unpubl.
89	Zusmarshausen	48°24' N	10°36' E	465	Vicus	small						Zach unpubl.
90	Aschhausen	48°11' N	11°43' E	512	Vicus	small	well, pit			w		Zach unpubl.
91	Seefelden	48°03' N	11°22' E	570	Vicus	small						Zach unpubl.
92	Weißenburg	49°07' N	10°46' E	421	Fort							Zach unpubl.
<b>Schweiz, Frankreich</b>												
93	Eschenz	47°39' N	8°52' E	395	Vicus	small	divers, waterlogged			w		Pollmann and Jacomet, 2012
94	Pfyn	47°36' N	8°57' E	436	Fort	small	pit	1	1	1	w	Jacomet, 2008
95	Oedenburg/Biesheim-Kunheim	48°04' N	7°34' E	187	Vicus	large	divers, waterlogged			27	w	Vandorpe, 2010
96	Oedenburg/Biesheim-Kunheim	48°04' N	7°34' E	187	Temple		divers, waterlogged			60	w	Vandorpe, 2010
97	Oberwinterthur	47°31' N	8°45' E	470	Vicus	small	divers, waterlogged			w		Jacquat, 1986
98	Neftenbach	47°31' N	8°40' E		Villa					w		Klee and Jacomet, 1999
<b>Rheinland-Pfalz, Hessen</b>												
99	Dalheim	49°50' N	8°18' E	179	Vicus	large	well			4	w	König, 1994
100	Tawern	49°40' N	6°34' E	210	Vicus	small	well			1	w	König, 1996
101	Groß-Gerau	49°55' N	8°29' E	87	Vicus	large	pit	47	77			Kreuz and Stika, 2009
102	Bad-Dürkheim-Ungstein	49°29' N	8°11' E	117	Villa			2	2			Piening, 1988
103	Bad-Dürkheim-Wachenheim	49°26' N	8°11' E	149	Villa			2	2			Piening, 1988
104	Cochem-Zell	50°02' N	7°11' E	100	grave			1	4	2		Piening, 1986
105	Eschborn	50°09' N	8°34' E	124	Villa		wells	2	3	5	w	Kreuz, 1996/97
106	Limburg-Greifenberg	50°24' N	8°04' E	182	Fort	small	ditch, oven	18	174	1242		Kreuz, 2020

ancient agricultural systems, such as *Plantago lanceolata*, *Trifolium repens*, *Trifolium pratense*, *Chrysanthemum leucanthemum*, *Prunella vulgaris* and *Phleum pratense*. Taking into account their present syntaxonomy or phytosociological behaviour, we assume that they represent an affinity to moderately fertilised pastures or meadows on arable land that corresponds to the ecological characteristics of fallow in the past.

## 2.2 Off-site data

Palynological data from seven palynological sites located in southwestern Germany were evaluated (Figure 1) in terms of woodland pasture and ruderal indicators. The pollen records are representative for different landscape types and related land use potential, such as: Upper Rhine valley (Allakistensee), Lake Constance (Mainau), the Lake Constance hinterland (Hartsee), Upper Swabia (Zellersee), South Black Forest (Titisee), North Black Forest (Herrenwieser See) and Allgäu (Großer Ursee). Expanding animal husbandry may also result in more woodland pasture, whereas the stabling of domestic herbivores or keeping them in fenced pastures (enclosures) would have the opposite effect. To explore the relative extent of woodland pasture in Roman times, the selected pollen records were evaluated for woodland grazing indicators according to Behre (1981), focussing on: *Calluna*, *Juniperus*, *Jasione montana*, *Phyteuma* type, Campanulaceae, *Melampyrum*, and *Pteridium*. The results are presented as sum-curves for all woodland pasture indicators with percentages based on the terrestrial pollen sum (Figure 6). We assume that manure production with dung heaps should trigger an increase in ruderal communities. Therefore, we evaluated all ruderal species (listed in Figure 6 caption) according to Behre (1981) and Oberdorfer (1970) in the pollen records and combined them into ruderal sum-curves (Figure 6) for each of the same selected pollen records.

## 3. Results

### 3.1 The on-site evidence

#### 3.1.1 Consumption by site types – diversity and ubiquity of edible plants

The diversity of the food plants (Figure 2) suggests a uniform picture of the cereal plants used (11 different taxa) at all site types. An exception are the ritual contexts – burials and temples. However, the ritual contexts are represented with only 4 sites in the current dataset and thus with far fewer sites and corresponding features than the other site types (see Table 1). Specific to this site type (ritual contexts) is that only these contain the imported species *Phoenix dactylifera* and *Pinus pinea*. All other site types are represented by at least 20 different sites and are thus suitable for evaluation of the crop diversity between them. Within these sites, the *villae rusticae* show the lowest diversity, while the forts and *vici* contain nearly one-third more different edible plant taxa. The diversity of the food plants is highest at the *vicus*

sites and especially at small (= rural) *vicus* sites with their high number of legumes, vegetables and spices, as well as both imported and gathered fruits and nuts. The differences in the number of species within the group of cultivated/imported fruits, between the *vicus* and *castellum* site types are insignificant ( $\sim n=20$ ), while in *villae rusticae* half of the diversity is due to cultivated or imported fruits ( $n=10$ ). In *vici* and *castelli*, the cultivated/imported fruits show similar species numbers ( $\sim n=20$ ), while in *villae rusticae* their diversity is much smaller ( $n=10$ ).

Of the 11 cereal species grown during this period, *Triticum spelta* and *Hordeum* have high ubiquity in all site types (Figure 3A). In large *vici*, all other cereals have low ubiquity. In forts and small villages (rural), all cereals have high ubiquity. In all site types and especially in *villae rusticae*, *Setaria italica* is rare. Of the legumes, *Vicia faba* is most frequent in forts. Also, oil and fibre plants as well as cultivated vegetables/spices have their highest ubiquity in forts (Table 2). The frequency of both cultivated and gathered fruits is significantly lower in *villae rusticae*, than in *vici* and *castella* (Figure 3C and 3D). If the charred archaeobotanical finds of those fruits are usually evidence for their consumption (van der Veen, 2007), it seems that the forts and *vici* were the main site types representing the Roman food culture in the region.

#### 3.1.2 Tillage intensity of the arable fields

According to the Archaeobotanical database of the Baden-Württemberg State Office for Cultural Heritage, charred seeds of *Plantago lanceolata*, one of the most important fallow indicators, are increasingly frequent in the archaeobotanical samples from the Late Bronze Age onwards and decrease sharply in the Roman period (Figure 4). Thereafter their ubiquity increased again during the Migration Period (ca. 300–500 AD), Merovingian period (500–750 AD) and Early Mediaeval period (750–1000 AD). The diachronic trends in the frequency per studied features are similar for *Trifolium repens*, *T. pratense*, *Chrysanthemum leucanthemum* and *Prunella vulgaris*. All these perennial fallow and grassland indicators first appear in the archaeobotanical record of south-western Germany in the Late Bronze Age and their frequency increases up to the La Tène period, while their lowest ubiquity is recorded in the Roman period (Figure 4). *Phleum pratense* was already quite common in the Early and Middle Bronze Age, but its highest frequency (more than 45%) is found in the features belonging to the La Tène period. During the Roman period, the frequency of *Phleum pratense* decreased significantly (to values below 5 %) (Figure 4) and subsequently it is even less frequent.

### 3.2 Off-site evidence

#### 3.2.1 Manuring indicators: ruderals and woodland pasture

At the site which was chosen as an example of marginal landscapes in Allgäu, Großer Ursee, the woodland pasture curve (Figure 5) shows a slight increase during the Roman period. At Zellsee, the site characteristic for the young



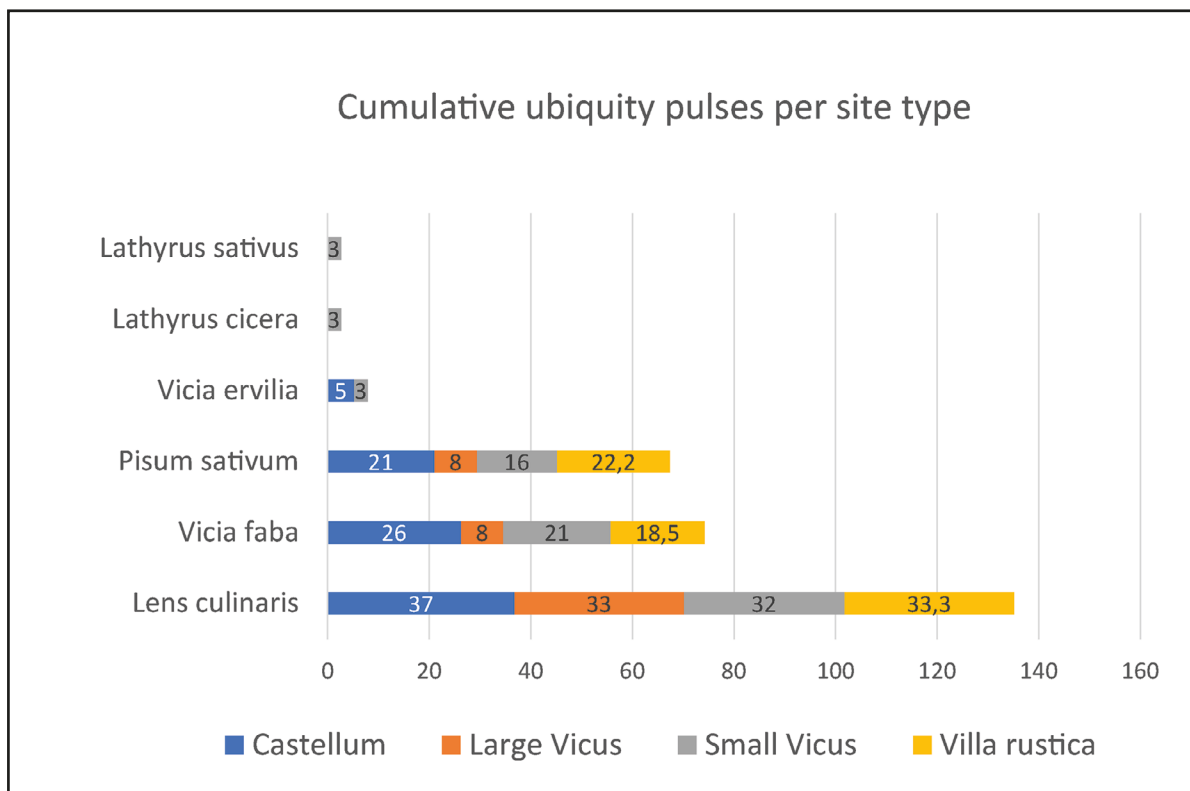
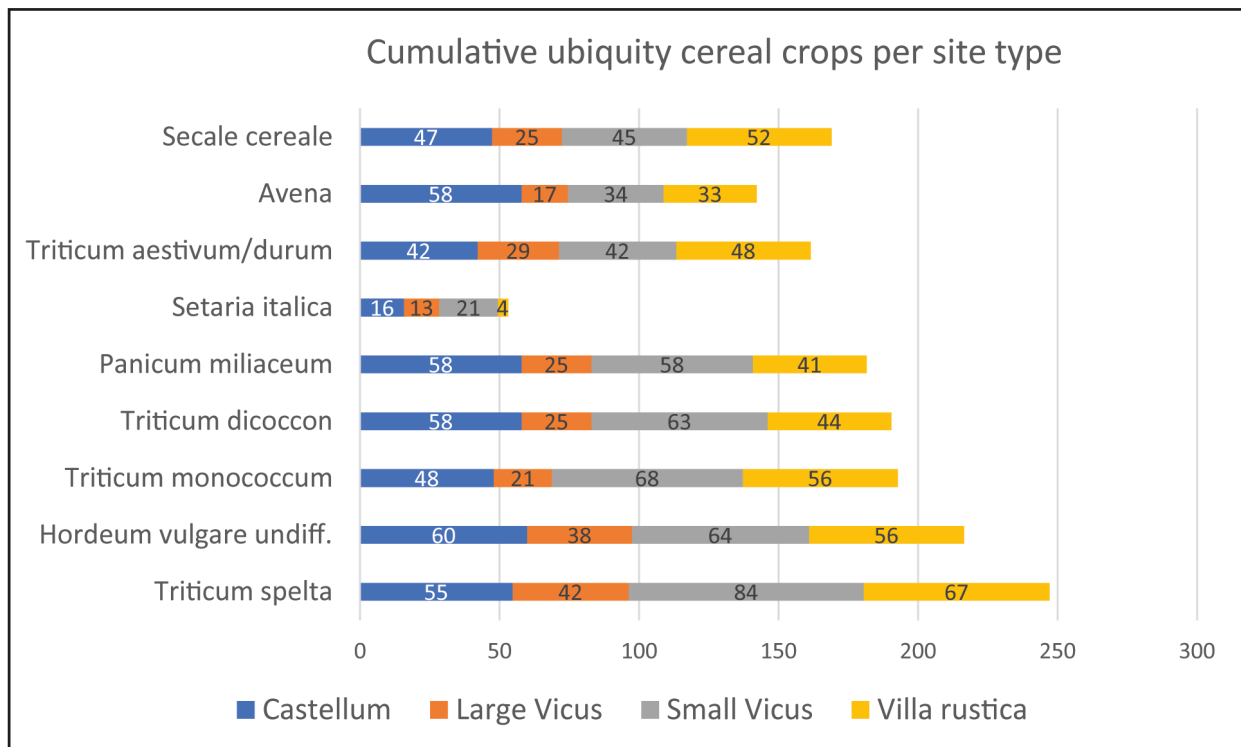


Figure 3. Site-based (n=106) ubiquity: A. of cereals (up); B. vegetables and spices (down).

moraine landscape of Upper Swabia, there is a slight increase in the pre-Roman Iron Age, but decrease in these pollen indicators during the Roman period. The pollen core from Mainau on Lake Constance, indicates a pronounced woodland pasture in general, but this decreases during the

Roman period. At Hartsee, situated in the Lake Constance hinterland, no differences in woodland grazing are discernible from the Late Bronze Age to the Early Mediaeval period. At Titisee, in the southern Black Forest, woodland grazing increases during the La Tène, Migration and Merovingian

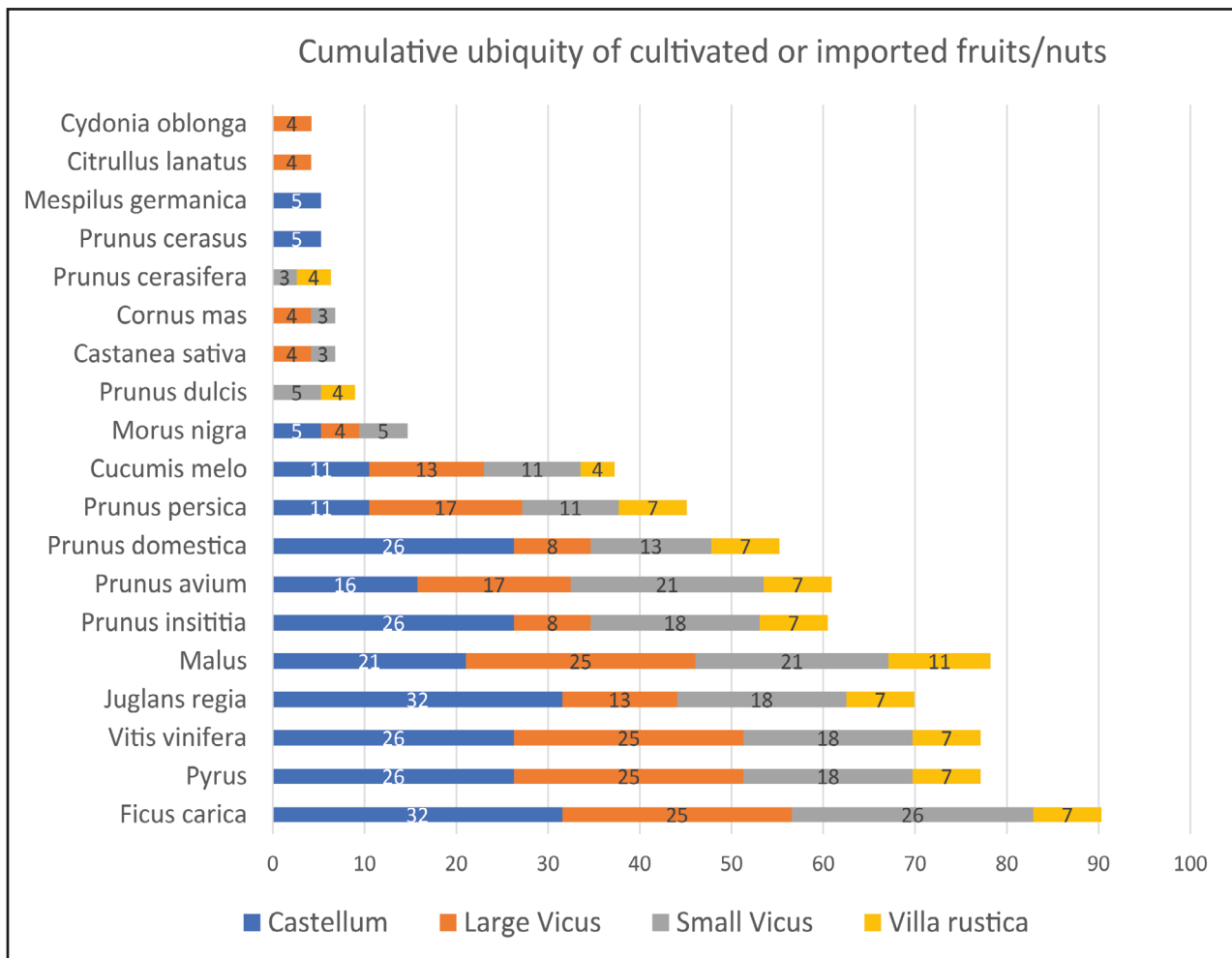


Figure 3. Site-based (n=106) ubiquity: C. cultivated fruits.

periods, while it is low during the Roman period. The same picture can be seen at Herrenwieser See in the northern Black Forest and at Aalkistensee, situated east of the Upper Rhine Plain. To conclude, the palynological evidence suggests that during the Roman period agricultural intensification did not involve manure production employing woodland grazing and woodland pasture was a rare strategy for animal husbandry in the study area during this same period. If used, manure must have been obtained by other means.

The picture shown by pollen indicators for ruderal areas suggests a decrease of such areas during the Roman period (Figure 6) at three out of seven sites. At Zellsee, Mainau and Aalkistensee, the ruderals clearly decrease from the previous pre-Roman Iron Age period. At two sites a slight, but insignificant, increase of ruderal species during the Roman period can be seen. An increase of the ruderals during the Roman period is more significant at Großer Ursee and Hartsee. To conclude, in the landscapes most suitable for agriculture, cropping increased and animal husbandry was less prominent, while in more marginal landscapes animal husbandry gained importance.

## 4. Discussion

### 4.1 Food plants at the different site types

The on-site evidence considered here points to significant differences in the food plants consumed between the *villae rusticae* and larger settlements like *vici* in urban contexts and forts. While staple crops, like pulses and especially cereals are the same (n=11 for cereal crops and n=6 for pulses) for all *villae rusticae*, *vici* and *castella*, the consumption of typical Roman plant-food-innovations, such as vegetables, spices and fruits (Körber-Grohne, 1979), is clearly pronounced in the military and urban settlement sites (Numbers 2, 6, 8, 13, 14, 20–23, 28, 43, 52–55, 60–63, 68, 72–75, 81 in Table 1).

The main cereals (spelt and barley) and pulses (lentil, pea, fava beans) most commonly cultivated in the Roman period in the study region correspond to those observed archaeobotanically for the preceding Iron Age (Rösch, 2021), suggesting a certain continuity in the crop production concerning the main staples (Table 3). Looking at the ubiquity of the cereal crops in the different site types, they also seem to show very consistent trends among each other,

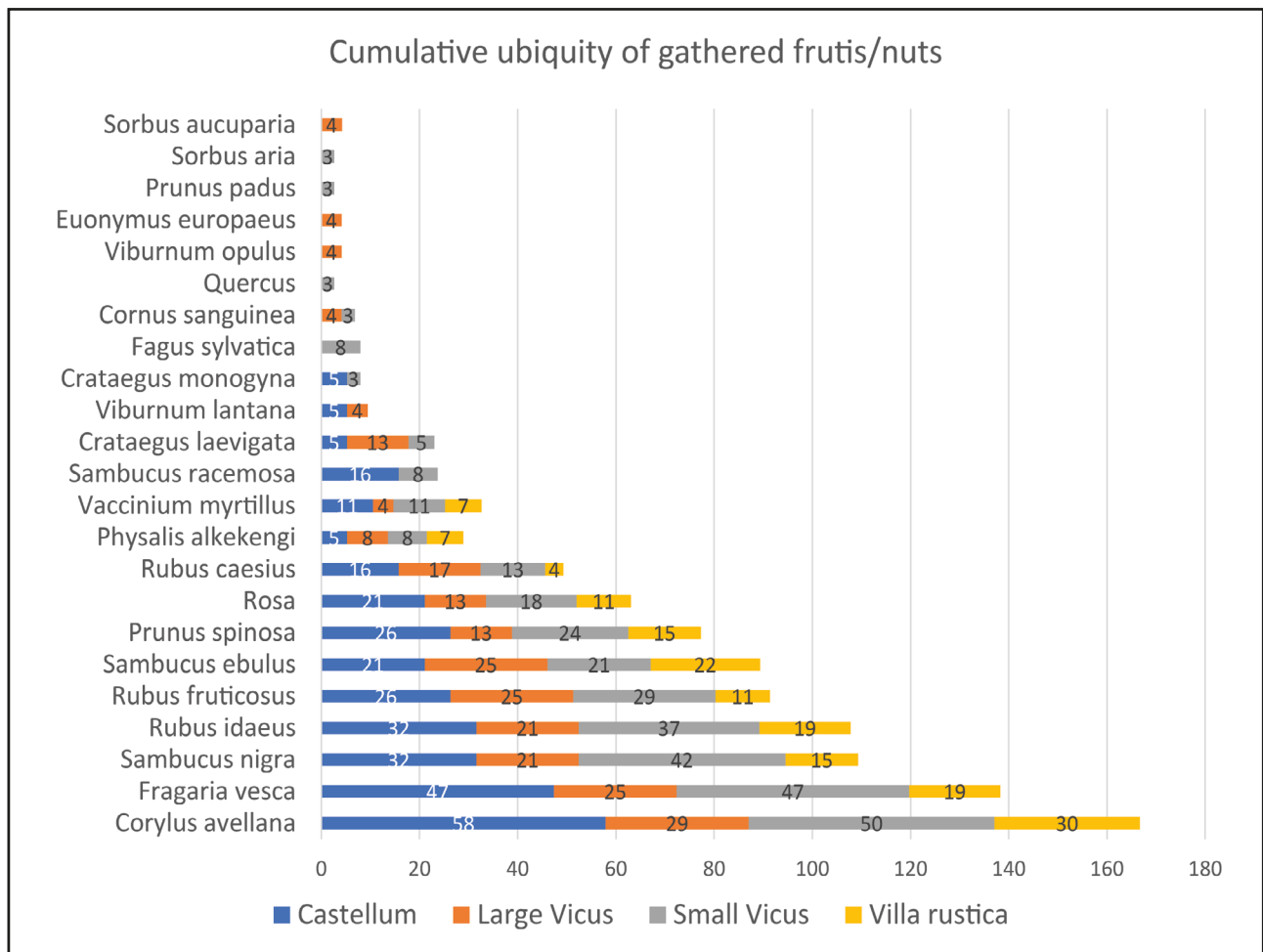


Figure 3. Site-based (n=106) ubiquity: D. gathered fruits.

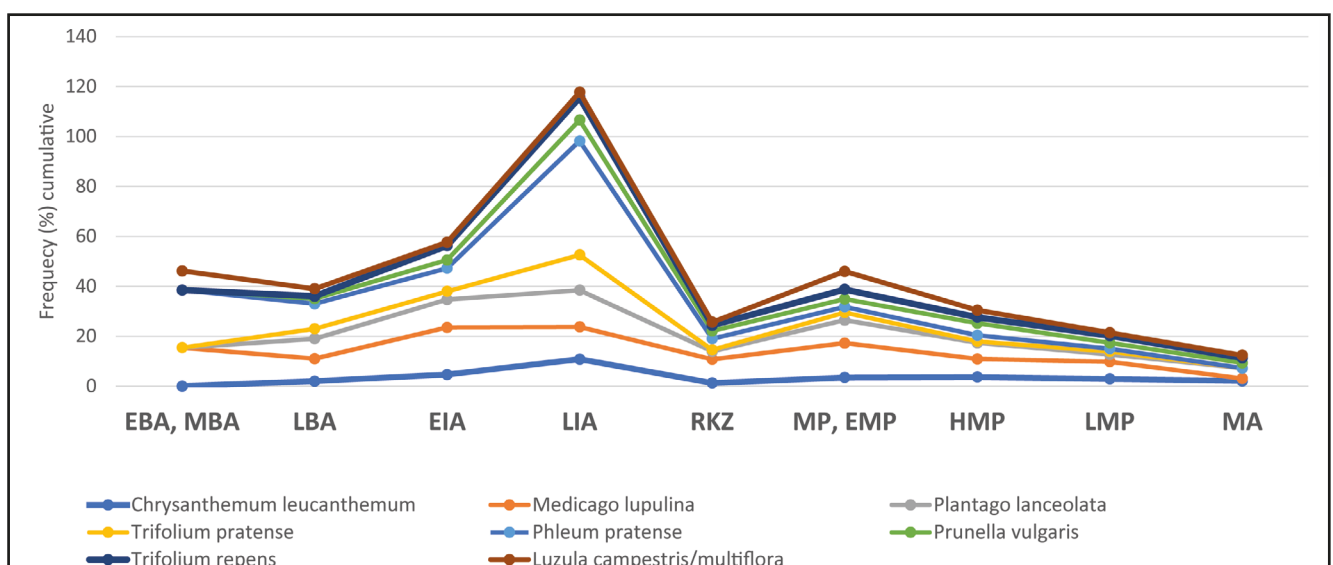


Figure 4. Feature-based ubiquity for charred remains from 248 archaeological sites of grassland plants for Bronze Age to Early Modern Times (*Trifolium repens*, *Prunella vulgaris*, *Phleum pratense*, *Trifolium pratense*, *Chrysanthemum leucanthemum*, *Plantago lanceolata*). Abbreviations: EBA/MBA: Early Bronze Age/Middle Bronze Age; LBA: Late Bronze Age; HS: Hallstatt; LT: La Tène; RP: Roman Period; MP/EMP: Migration Period/Early Mediaeval Period; HMP: High Mediaeval Period; LMP: Late Mediaeval Period; EMA: Early Modern Age.

**Table 2.** Feature-based ubiquities of the main edible plants per site type.

	<i>Castellum</i>	<i>Large Vicus</i>	<i>Small Vicus</i>	<i>Villa rustica</i>		<i>Castellum</i>	<i>Large Vicus</i>	<i>Small Vicus</i>	<i>Villa rustica</i>
<b>Cereal crops</b>					<i>Ruta graveolens</i>	5.3	4.2	5.3	
<i>Triticum spelta</i>	55	42	84	67	<i>Petroselinum crispum</i>	5.3		5.3	3.7
<i>Hordeum vulgare undiff.</i>	60	38	64	56	<i>Rumex scutatus</i>	5.3		7.9	
<i>Triticum monococcum</i>	48	21	68	56	<i>Brassica oleracea</i>	5.3		2.6	
<i>Triticum dicoccon</i>	58	25	63	44	<i>Allium sativum</i>			2.6	3.7
<i>Panicum miliaceum</i>	58	25	58	41	<i>Allium cult.</i>		8.3		
<i>Setaria italica</i>	16	13	21	4	<i>Pimpinella anisum</i>		8.3		
<i>Triticum aestivum/durum</i>	42	29	42	48	<i>Amaranthus lividus</i>	5.3		2.6	
<i>Avena</i>	58	17	34	33	<i>Brassica nigra</i>	5.3		2.6	
<i>Secale cereale</i>	47	25	45	52	<i>Piper nigrum</i>		4.2	2.6	
<i>Hordeum vulgare</i>	10.5	8.3	39.5	18.5	<i>Lactuca sativa</i>			2.6	3.7
<b>Pulses</b>					<i>Hyssopus officinalis</i>	5.3			
<i>Lens culinaris</i>	37	33	32	33.3	<i>Levisticum officinale</i>	5.3			
<i>Vicia faba</i>	26	8	21	18.5	<i>Raphanus sativus</i>	5.3			
<i>Pisum sativum</i>	21	8	16	22.2	<i>Satureja montana</i>	5.3			
<i>Vicia ervilia</i>	5		3		<i>Cichorium endivia</i>		4.2		
<i>Lathyrus cicera</i>			3		<i>Eruca sativa</i>		4.2		
<i>Lathyrus sativus</i>			3		<i>Lepidium sativum</i>		4.2		
<b>Oil-/Fiber crops</b>					<i>Majorana hortensis</i>		4.2		
<i>Papaver somniferum</i>	47	17	24	15	<i>Nigella sativa</i>		4.2		
<i>Linum usitatissimum</i>	37	17	21	15	<i>Salvia officinalis</i>		4.2		
<i>Camelina sativa</i>	16	21	11	7	<i>Sinapis alba</i>			2.6	
<i>Olea europaea</i>	5	8	5		<i>Thymus vulgaris</i>			2.6	
<i>Cannabis sativa</i>		4	8	4	<i>Cuminum cyminum</i>		4.2		
<i>Camelina</i>	5	8	5		<i>Melissa officinalis</i>		4.2		
<i>Carthamus tinctorius</i>					<i>Carum carvi</i>				
<b>Vegetables and spices (cultivated or gathered)</b>					<i>Humulus lupulus</i>	10.5	8.3	7.9	
<i>Anethum graveolens</i>	31.6	29.2	26.3	7.4	<i>Juniperus communis</i>		12.5	10.5	
<i>Coriandrum sativum</i>	36.8	20.8	21.1	7.4		5.3	7.9	3.7	
<i>Apium graveolens</i>	21.1	16.7	21.1	3.7	<b>Fruits and nuts, cultivated or imported</b>				
<i>Satureja hortensis</i>	15.8	12.5	15.8	7.4	<i>Ficus carica</i>	32	25	26	7
<i>Beta vulgaris</i>	26.3	8.3	10.5	3.7	<i>Pyrus</i>	26	25	18	7
<i>Atriplex hortensis</i>	15.8	8.3	5.3	7.4	<i>Vitis vinifera</i>	26	25	18	7
<i>Brassica rapa</i>	5.3	8.3	13.2	3.7	<i>Juglans regia</i>	32	13	18	7
<i>Lagenaria sicceraria</i>	5.3	8.3	2.6		<i>Malus</i>	21	25	21	11
<i>Foeniculum vulgare</i>		12.5	5.3		<i>Prunus insititia</i>	26	8	18	7
<i>Cucumis sativus</i>	5.3	8.3			<i>Prunus avium</i>	16	17	21	7
					<i>Prunus domestica</i>	26	8	13	7
					<i>Prunus persica</i>	11	17	11	7

**Table 2.** Feature-based ubiquities of the main edible plants per site type. (Continuation)

	<i>Castellum</i>	<i>Large Vicus</i>	<i>Small Vicus</i>	<i>Villa rustica</i>		<i>Castellum</i>	<i>Large Vicus</i>	<i>Small Vicus</i>	<i>Villa rustica</i>
<i>Cucumis melo</i>	11	13	11	4	<i>Sambucus ebulus</i>	21	25	21	22
<i>Morus nigra</i>	5	4	5		<i>Prunus spinosa</i>	26	13	24	15
<i>Prunus dulcis</i>			5	4	<i>Rosa</i>	21	13	18	11
<i>Castanea sativa</i>		4	3		<i>Rubus caesius</i>	16	17	13	4
<i>Cornus mas</i>		4	3		<i>Physalis alkekengi</i>	5	8	8	7
<i>Prunus cerasifera</i>			3	4	<i>Vaccinium myrtillus</i>	11	4	11	7
<i>Prunus cerasus</i>	5				<i>Sambucus racemosa</i>	16		8	
<i>Mespilus germanica</i>	5				<i>Crataegus laevigata</i>	5	13	5	
<i>Citrullus lanatus</i>		4			<i>Viburnum lantana</i>	5	4		
<i>Cydonia oblonga</i>		4			<i>Crataegus monogyna</i>	5		3	
<i>Phoenix dactylifera</i>					<i>Fagus sylvatica</i>			8	
<i>Pinus pinea</i>					<i>Cornus sanguinea</i>		4	3	
					<i>Quercus</i>			3	
<b>Fruits and nuts, gathered</b>					<i>Viburnum opulus</i>		4		
<i>Corylus avellana</i>	58	29	50	30	<i>Euonymus europaeus</i>		4		
<i>Fragaria vesca</i>	47	25	47	19	<i>Prunus padus</i>			3	
<i>Sambucus nigra</i>	32	21	42	15	<i>Sorbus aria</i>			3	
<i>Rubus idaeus</i>	32	21	37	19	<i>Sorbus aucuparia</i>		4		
<i>Rubus fruticosus</i>	26	25	29	11					

**Table 3.** Food plants known from the archaeobotanical records in the study area before, after and during the Roman Age.

<b>Period</b>	<b>Iron Age</b>	<b>Roman</b>	<b>Migration Period</b>		<b>Period</b>	<b>Iron Age</b>	<b>Roman</b>	<b>Migration Period</b>
<b>Cereals</b>				<b>Pulses</b>				
<i>Avena</i>	X	X	X	<i>Lathyrus cicera</i>	–	X	–	–
<i>Hordeum distichon</i>	–	–	X	<i>Lathyrus sativus</i>	–	X	–	–
<i>Hordeum vulgare</i>	X	X	–	<i>Lens culinaris</i>	X	X	X	X
<i>Hordeum vulgare undiff.</i>	X	X	X	<i>Pisum sativum</i>	X	X	X	X
<i>Panicum miliaceum</i>	X	X	X	<i>Vicia ervilia</i>	X	X	X	X
<i>Secale cereale</i>	X	X	X	<i>Vicia faba</i>	X	X	X	X
<i>Setaria italica</i>	X	X	X	<i>Oil- and fiber plants</i>				
<i>Triticum aestivum/durum</i>	X	X	X	<i>Brassica rapa s.l.</i>	X	–	X	–
<i>Triticum cf. timophevii</i>	X	–	–	<i>Camelina</i>	X	X	X	X
<i>Triticum dicoccon</i>	X	X	X	<i>Camelina sativa</i>	X	X	X	X
<i>Triticum monococcum</i>	X	X	X	<i>Cannabis sativa</i>	X	X	X	X
<i>Triticum spelta</i>	X	X	X	<i>Carthamus tinctorius</i>	–	X	–	–

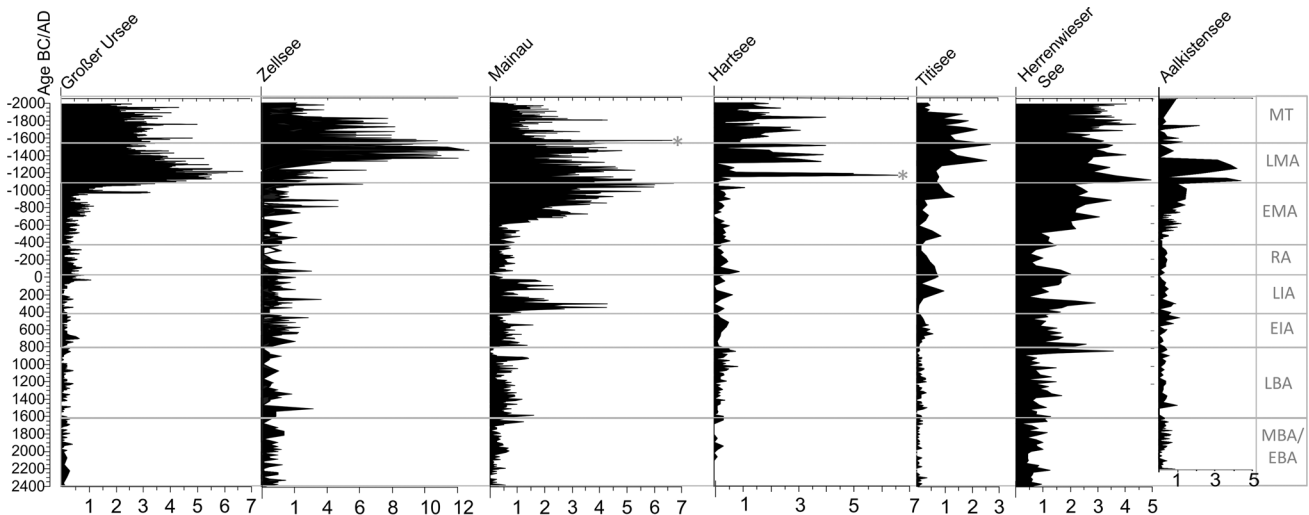


**Table 3.** Food plants known from the archaeobotanical records in the study area before, after and during the Roman Age. (Continuation)

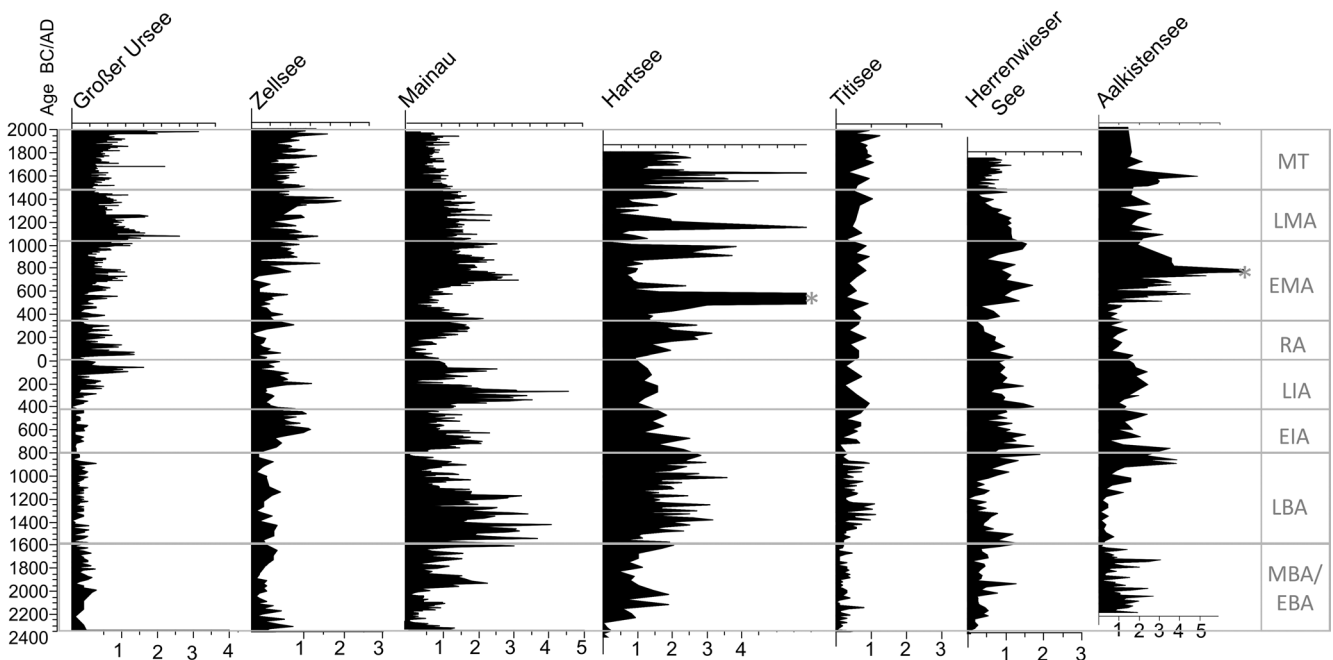
Period	Iron Age	Roman	Migration Period	Period	Iron Age	Roman	Migration Period
<i>Linum usitatissimum</i>	X	X	X	<i>Ruta graveolens</i>	–	X	–
<i>Olea europaea</i>	–	X	–	<i>Salvia officinalis</i>	–	X	–
<i>Papaver somniferum</i>	X	X	X	<i>Satureja hortensis</i>	–	X	X
<b>Vegetables, spices</b>				<i>Satureja montana</i>	–	X	X
<i>Allium cult.</i>	–	X	–	<i>Sinapis alba</i>	–	X	X
<i>Allium sativum</i>	–	X	–	<i>Thymus vulgaris</i>	–	X	–
<i>Amaranthus lividus</i>	X	X	X	<b>Collected</b>			
<i>Anethum graveolens</i>	X	X	X	<i>Carum carvi</i>	X	X	–
<i>Apium graveolens</i>	X	X	X	<i>Humulus lupulus</i>	X	X	X
<i>Artemisia absinthium</i>	–	–	X	<i>Juniperus communis</i>	–	X	X
<i>Atriplex hortensis</i>	–	X	–	fruits, nuts			
<i>Beta vulgaris</i>	–	X	X	<i>Castanea sativa</i>	–	X	–
<i>Brassica nigra</i>	–	X	–	<i>Citrullus lanatus</i>	–	X	–
<i>Brassica oleracea</i>	–	X	X	<i>Cornus mas</i>	–	X	X
<i>Brassica rapa</i>	–	X	–	<i>Cucumis melo</i>	–	X	–
<i>Cichorium endivia</i>	–	X	–	<i>Cydonia oblonga</i>	–	X	–
<i>Coriandrum sativum</i>	–	X	X	<i>Ficus carica</i>	X	X	X
<i>Cucumis sativus</i>	–	X	–	<i>Juglans regia</i>	–	X	X
<i>Cuminum cyminum</i>	–	X	–	<i>Malus</i>	X	X	X
<i>Eruca sativa</i>	–	X	–	<i>Mespilus germanica</i>	–	X	–
<i>Foeniculum vulgare</i>	–	X	–	<i>Morus nigra</i>	–	X	–
<i>Hyssopus officinalis</i>	–	X	–	<i>Phoenix dactylifera</i>	–	X	–
<i>Lactuca sativa</i>	–	X	–	<i>Pinus pinea</i>	–	X	–
<i>Lagenaria sicceraria</i>	–	X	X	<i>Prunus avium</i>	X	X	X
<i>Lepidium sativum</i>	–	X	–	<i>Prunus cerasifera</i>	–	X	–
<i>Levisticum officinale</i>	–	X	–	<i>Prunus cerasus</i>	–	X	–
<i>Majorana hortensis</i>	–	X	X	<i>Prunus domestica</i>	–	X	–
<i>Melissa officinalis</i>	–	X	X	<i>Prunus dulcis</i>	–	X	–
<i>Nigella sativa</i>	–	X	–	<i>Prunus insititia</i>	–	X	X
<i>Petroselinum crispum</i>	X	X	X	<i>Prunus persica</i>	–	X	X
<i>Pimpinella anisum</i>	–	X	–	<i>Pyrus</i>	X	X	X
<i>Piper nigrum</i>	–	X	–	<i>Vitis vinifera</i>	–	X	X
<i>Raphanus sativus</i>	–	X	–	<b>Total</b>	31	82	45
<i>Rumex scutatus</i>	–	X	–				

with the highest values for spelt, implying that it was the most important staple cereal crop during the Roman period as already suggested in previous studies (Rösch *et al.*, 1992). The constant presence of *Hordeum vulgare* grains could be due to a dual use: on the one hand, barley can be an element of human nutrition (food and beer), but on the other hand it can

be used as fodder for livestock (Stika, 1996). Interestingly, the large *vici* sites show significantly lower overall ubiquity values for cereals as well as for pulses compared to the small *vici* and *castella*. A possible explanation could be that at these larger sites the structures where frequently charred remains of staple food plants (cereals and pulses) occur,



**Figure 5.** Indicators for woodland pasture expressed as sum curve per site. Pollen types considered *Juniperus communis*, *Melampyrum*, *Calluna vulgaris*, *Pteridium aquilinum*, *Genista* type., *Ilex aquifolium*, *Cytisus*, and *Polypodium vulgare*. Percentages based on the terrestrial pollen sum.



**Figure 6.** Indicators for ruderal communities in the considered pollen profiles, expressed as sum curve per site. Pollen types considered: *Artemisia*, *Urtica*, *Chenopodiaceae*, *Plantago major*, *Sambucus nigra/racemosa*, *Daucus carota*, *Chaerophyllum hirsutum* type, *Sambucus ebulus*, *Aegopodium podagraria*, *Aethusa cynapium*, *Anthriscus sylvestris*, *Arctium lappa* type, *Ballota* type, *Carduus* type, *Chaenarrhinum minus*, *Chaerophyllum aureum*, *Chaerophyllum bulbosum*, *Chelidonium majus*, *Circaea*, *Cirsium*, *Conium maculatum*, *Cuscuta europaea* type, *Echium*, *Eupatorium cannabinum* type, *Falcaria vulgaris* type, *Galeopsis* type, *Geranium pusillum* type, *Geum* type, *Heracleum sphondylium* type, *Hyoscyamus niger*, *Lamium album* type, *Ornithogalum umbellatum* type, *Pastinaca sativa*, *Polygonum aviculare*, *P. persicaria* type, *Reseda*, *Rumex aquaticus* type, *Rumex obtusifolium* type, *Silene vulgaris* type, *Solanum dulcamara*, *Torilis japonica*, *Verbascum*, and *Verbena officinalis*. Percentages based on the terrestrial pollen sum.

such as ovens and hearths (van der Veen, 2007), had less occasion to be sampled. However, to draw more reliable conclusions from this observation, further context-based and fully quantitative analyses of the current dataset are needed.

Looking at the ubiquity of oil and fibre crops (Table 2), poppy and linseed and the imported fruits of olives seem to be the most important within this group. Olives were mainly consumed in an urban context (the same sites as listed above), again indicating the importance of these imported plant foods at urban or military centres. The main

consumption sites for vegetables and spices seem to be *castella* (Table 2). In contrast, imported and cultivated fruits and nuts are ubiquitous at both *castella* and *vici* (Figures 3C and 3D). This confirms that the fundamental changes in diet and food habits manifested themselves most strongly in the urban contexts. A possible explanation for this phenomenon is the importance of urban markets and military camps for the distribution and consumption of new foods (Kreuz, 2005; Livarda, 2011), while in the rural places, the pre-Roman Iron Age plant food traditions persisted (Table 3). Concerning

the local production, it is obvious that *Olea* and *Piper* were imported, due to their climatically-determined growth restrictions. All others, including *Vicia ervilia*, *Lathyrus cicera/sativus*, *Pimpinella anisum*, *Cuminum cyminum*, *Lagenaria sicceraria*, *Ficus carica*, *Cucumis melo*, *Prunus dulcis*, *Mespilus germanica*, *Citrullus lanatus* can be cultivated in southern Germany, and we assume their local production. Most probably the cereals for the military camps were also produced locally, as a comparison of crop weeds from the Roman military sites Welzheim, Murrhardt and Mainhardt show. These weeds reflect the local soil conditions (Körber-Grohne *et al.*, 1983; Rösch, 1989; Körber-Grohne and Rösch, 1988).

#### 4.2 Land use features according to on-site and off-site evidence

The frequency of all evaluated grassland/fallow land plants (perennials) from the on-site records decreases during the Roman period (Figure 4). Therefore, this period seems to be the main one characterised by agricultural intensification in the form of deeper and more frequent tillage and shorter fallow periods that would suppress the development of these perennials. This process may have begun as early as the La Tène period, based on the palynological evidence from south-western Germany (Tserendorj *et al.*, 2021). The written sources point to the practice of more intensive tillage, such as described in the 1<sup>st</sup> century AD by Plinius the Elder, who mentions the mouldboard plough (cited after König *et al.*, 1995). Looking at the zooarchaeological evidence from Roman Raetia, a tendency towards selective breeding for larger and more efficient animals can be observed (Trixl *et al.*, 2017). The increasing importance of animal husbandry strategies, not only related to meat production, but also to draught (pulling) power and agricultural activities such as ploughing in the context of large-scale production, were also observed in the study area (Grau-Sologestoa *et al.*, 2022).

The intensification of annual crop cultivation observed in the Roman period was most likely triggered by the need to generate certain surpluses. This could be achieved by extending the arable land and/or by applying manure to achieve higher yields on the same area. The nitrogen-demanding ruderal plants, growing abundantly on dung heaps or in places where animal excrement accumulates can be used as indicators of manure management. However, considering these pollen indicators, ruderals are much more common in the Middle Ages than in the Roman period (Figure 6). While the pollen profiles show a slight increase of ruderals already during the Iron Age, those values decreased during the Roman period. Thus, it seems that keeping dung heaps and similar accumulations was not a substantial part of the region's agricultural practices during Roman times. Bio-archaeological studies from north-eastern Gaul using stable isotope analyses of archaeobotanical remains and considering  $\delta^{15}\text{N}$  values in crops as a scale of intensity of manuring suggest that at least some manuring was applied during the Roman Period (Aguilera *et al.*, 2017). However,

such results have to be considered cautiously as plant-available nitrogen in the soil during growth is influenced by several other factors such as original soil quality, temperature, moisture, slope exposure, former settlement, and land use, *etc.* (Dreslerová *et al.*, 2021).

Woodland grazing, as one of the sources for animal feeding and subsequent manure production, has also been considered. Sum-curves of the woodland grazing indicators in the studied pollen profiles from South Germany show the highest grazing pressure during the Mediaeval period (Figure 5). A slight increase can be seen earlier in most of the pollen profiles, more specifically in the pre-Roman Late Iron Age. Thus, the Romans did not increase manure production by extensive woodland grazing, but rather by other animal husbandry methods. In order to keep the agricultural system productive, they must have increased nutrient input, and most likely did so by more intensive animal husbandry, perhaps by keeping the animals in fenced pastures, or grazing the stubble fields (Halstead, 2014). Keeping animals in enclosures during the Roman period is not only known for domestic animals, but even for wild animals such as deer (Kokabi and Becker, 1997).

The written evidence confirms the use of both manuring as well as the alternation between arable and fallow land during the Roman period (Columella, 2014). The ratio of cultivated land to fallow land as inferred by the *Cerealia/Plantago lanceolata* index points to the greatest agricultural intensification in the Roman period in south-western Germany, compared to earlier periods (Tserendorj *et al.*, 2021). The decreasing fallow-land indicators, according to both macro-botanical (Figure 4) and pollen records, confirm that the Romans practised a well-developed and sophisticated agriculture not only in Italy, but also in the northern provinces, with appropriate measures to obtain sufficient yields. Therefore, agricultural intensification seems to be evident and besides intensive ploughing and shortening of the fallow period, likely a certain manuring input should be plausible too.

## 5. Conclusions

The plant macrofossil findings considered here show substantial shifts in plant food diversity between different site types, while the palynological evidence points to certain intensification of the agriculture during the Roman period in the provinces of Upper Germania and Raetia.

While the main staple crops are the same in all site types, the fruits and vegetables/spices were more common in the diet of the inhabitants of forts and urban *vici*. The differences between the site types indicate a lower food plant diversity in *villae rusticae* compared to other site types, a situation similar to that observed for the Mediaeval period in the study area, *i.e.* higher food diversity in towns compared to rural sites. The staple cereal crops and pulses are more or less the same as during the pre-dating Iron Age and subsequent Migration period, while the diversity of the fruits, vegetables

and spices increases considerably during the Roman period compared to the Iron Age. After the Roman period, during the subsequent Migration period, it decreases again, albeit less pronounced.

The decrease of indicators for long-term fallow land in the plant macrofossil assemblages from the Roman period in the study area points to shortening of the fallow intervals and better ploughing compared to the previous periods. The pollen indicators for woodland pasture and ruderal areas do not show clear evidence for systematic manuring, but provide some hints for the initial stages of it. Thus, according to the combined palynological and plant macrofossil evidence, it seems that during the Roman period the cropping system in the study area began to evolve towards shorter fallow periods and some application of manure. This practice allowed for the higher crop production needed for the growing population and trade. At the same time, it can be considered as the first step towards the intensification of agriculture in the sense of arable field agriculture and field rotation systems, which were developed further later on, during the Mediaeval period.

## Acknowledgements

The authors thank Tanja Märkle, Marion Sillmann, Gegensuvd Tserendorj, and Michael Scheu for technical help. Sabine Rieckhoff gave helpful comments to an earlier draft. We are also grateful to the editor and two anonymous reviewers for the helpful comments on the first version of the manuscript.

## References

AGUILERA, M., ZECH-MATTERNE, V., LEPETZ, S., and BALASSE, M., 2017. Crop Fertility Conditions in North-Eastern Gaul during the La Tène and Roman Periods: A Combined Stable Isotope Analysis of Archaeobotanical and Archaeozoological Remains. *Environmental Archaeology*, 23, 323–337.

BAAS, J., 1974. Kultur- und Wildpflanzenreste aus einem römischen Brunnen von Rottweil-Altstadt. *Fundberichte aus Baden-Württemberg*, 1, 373–416.

BAKELS, C.C., WESSELINGH, D., and AMEN, I., 1997. Acquiring a taste: the diet of Iron Age and Roman period farmers at Oss-Ussen, the Netherlands. *Analecta Praehistorica Leidensia*, 29, 193–211.

BAKELS, C., and JACOMET, S., 2003. Access to luxury foods in Central Europe during the Roman period: the archaeobotanical evidence. *World Archaeology*, 34, 542–557.

BEHRE, K.E., 1981. The interpretation of anthropogenic indicators in pollen diagrams. *Pollen Spores*, 23, 225–245.

BOGAARD, A., HODGSON, J., NITSCH, E., JONES, G., STYRING, A., DIFFEY, C., POUNCETT, J., HERBIG, C., CHARLES, M., ERTUĞ, F., TUGAY, O., FILIPOVIC, D., and FRASER, R., 2016. Combining functional weed ecology and crop stable isotope ratios to identify cultivation intensity: a comparison of cereal production regimes in Haute Provence, France and Asturias, Spain. *Vegetation History and Archaeobotany*, 25, 57–73.

COLUMELLA, L. I. M. 2014. Zwölf Bücher über Landwirtschaft (De re rustica, translated and edited by W. Richter), Tusculum collection, vol. 2, München: Artemis Publishing House.

DRESLEROVÁ, D., HAJNALOVÁ, M., TRUBAČ, J., CHUMAN, T., KOČÁR, P., KUNZOVÁ, E., and ŠEFRNA, L., 2021. Maintaining

soil productivity as the key factor in European prehistoric and Medieval farming. *Journal of Archaeological Science: Reports*, 35, 102633. DOI: 10.1016/j.jasrep.2020.102633

DREXHAGE, H.J., KONEN, H.C., and RUFFING, K., 2002. *Die Wirtschaft des Römischen Reiches*. Berlin: Akademie-Verlag.

FIETZ, A., 1961. Pflanzenreste aus den römischen Brunnen in Pforzheim. *Beiträge zur naturkundlichen Forschung in Südwestdeutschland*, 20(1), 23–29.

FRANK, K.S., and STIKA, H.P., 1988. *Bearbeitung der makroskopischen Pflanzen- und einiger Tierreste des Römerkastells Sablonetum (Ellingen bei Weissenburg in Bayern)*. Kallmünz: Lassleben.

FRÖSCHLE, B., 1994. *Botanische Untersuchungen römerzeitlicher Pflanzenreste aus der archäologischen Ausgrabung in Osterburken*. Unpublished thesis (MA), University Hohenheim.

FÜNFSCHILLING, S., JACQUAT, C., SCHIBLER, J., and ZÜRCHER, A., 1985. Pflanzenbau, Nahrungsmittel und Essgewohnheiten im römischen Vicus Vitodurum – Oberwinterthur. *Archäologie der Schweiz*, 8, 160–167.

GRAU-SOLOGESTOA, I., GROOT, M., and DESCHLER-ERB, S., 2022. Innovation and Intensification: The Use of Cattle in the Roman Rhine Region. *Environmental Archaeology*, 2022, 1–19. DOI: 10.1080/14614103.2022.2090094

HALSTEAD, P., 2014. *Two oxen ahead. Pre mechanized farming in the Mediterranean*. Oxford: Willey Blackwell.

HEJCMAN, M., HEJCMANOVÁ, P., PAVLŮ, V., and BENEŠ, J., 2013. Origin and history of grasslands in Central Europe – a review. *Grassland and Forage Science*, 68, 345–363.

HUGONOT, J.C., KOKABI, M., RÖSCH, M., and WAHL, J., 1991. Die Villa rustica von Lomersheim, Stadt Mühlacker, Enzkreis. *Fundberichte aus Baden-Württemberg*, 16, 175–213.

JACOMET, S., 2008. Archäobotanische Grobanalyse der untersten Verfüllschicht aus der spätrömischen Grube 2001.013.97.1 bei der Kastellmauer in Pfyn. In: *AD FINES. Das spätrömische Kastell Pfyn Band 1: Befunde und Funde*. Frauenfeld: Amt für Archäologie Thurgau, pp. 229–230.

JACOMET, S., 2014. Crop diversity in Southwestern Central Europe from the Neolithic onward. In: A. Chevalier, E. Marinova, and L. Peña-Chocarro, eds. *Plants and People: Choices and Diversity through Time*. EARTH Monographs Book, 1, Oxford: Oxbow, pp. 82–95.

KLEE, M., and JACOMET, S., 1999. Ackerbau und Grünlandwirtschaft: Ergebnisse der archäobotanischen Untersuchungen. In: J. Rychener, and P. Della Casa, eds. *Der römische Gutshof in Neftenbach*. Zürich: Zürich und Egg, pp. 464–472.

KLOFT, H., 2005. *Die Wirtschaft des Imperium Romanum*. Mainz: von Zabern.

KNOPF, T., FISCHER, E., KÄMPF, L., WAGNER, H., WICK, L., DUPRAT-OALID, F., FLOSS, H., FREY, T., LOY, A.K., MILLET, L., RIUS, D., BRÄUNING, A., FEGER, K.-H., and RÖSCH, M., 2019. Archäologische und naturwissenschaftliche Untersuchungen zur Landnutzungsgeschichte des Südschwarzwalds. *Fundberichte aus Baden-Württemberg*, 39, 19–101.

KÖNIG, M., 1994. Die Pflanzenfunde. In: E. Goddard, ed. *Eine Brunnenverfüllung aus dem römischen Vicus Dalheim*. Hémecht, 46, pp. 798–810.

KÖNIG, M., 1996. Pflanzenreste aus dem römischen Vicus Tawern. Ein Beitrag zu Landwirtschaft und Umwelt. *Funde und Ausgrabungen im Bezirk Trier*, 28, 31–40.

KÖRBER-GROHNE, U., 1979. *Nutzpflanzen und Umwelt im römischen Germanien*. Kleine Schriften zur Kenntnis der römischen Besatzungsgeschichte in Südwestdeutschland, 21, Aalen: Limesmuseum.

KÖRBER-GROHNE, U., 1993. Wirtschaftsgrünland in römischer und vorrömischer Eisenzeit. In: A.J. Kalis, and J. Meurers-Balke, eds. *7000 Jahre bäuerliche Landschaft: Entstehung, Erforschung, Erhaltung*. Festschrift K.-H. Knörzer. Archaeo-Physica, 13, Köln: Rheinland-Verlag, pp. 105–112.

KÖRBER-GROHNE, U., and PIENING, U., 1979. Verkohlte Nutz- und Wildpflanzenreste aus Bondorf, Kreis Böblingen. *Fundberichte aus Baden-Württemberg*, 4, 152–169.

KÖRBER-GROHNE, U., and PIENING, U., 1983. Die Pflanzenreste aus dem Ostkastell von Welzheim mit besonderer Berücksichtigung der Graslandpflanzen. In: U. Körber-Grohne, M. Kokabi, U. Piening,



- and D. Planck, eds. *Flora und Fauna im Ostkastell von Welzheim. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg*, 14, Stuttgart: Theiss, pp. 17–88.
- KÖRBERGROHNE, U., and RÖSCH, M., 1988. Römerzeitliche Brunnenfüllung im Vicus von Mainhardt, Kreis Schwäbisch Hall. *Fundberichte aus Baden-Württemberg*, 13, 307–323.
- KOKABI, M., and BECKER, T., 1997. Betriebsorientierung der römischen Gutshöfe. *Beiträge zur Archäozoologie und prähistorischen Anthropologie*, 1, 23–29.
- KREBS, P., ULMKE, F., TINNER, W., and CONEDERA, M., 2022. The Roman Legacy on European Chestnut and Walnut Arboriculture. *Environmental Archaeology*, 2022, 1–22. DOI: 10.1080/14614103.2022.2137648.
- KREUZ, A., 1996/1997. Archäobotanische Untersuchung von Brunnenproben der römischen Fundstelle Eschborn, Baugebiet „Dörnweg“. *Berichte der Kommission für archäologische Landesforschung in Hessen*, 4, 61–77.
- KREUZ, A., 2005. Landwirtschaft im Umbruch? Archäobotanische Untersuchungen zu den Jahrhunderten um Christi Geburt in Hessen und Mainfranken. *Bericht der Römisch-Germanischen Kommission*, 85, 97–292.
- KREUZ, A., 2020. Archäobotanische Untersuchung der spätlatenezeitlichen und römischen Befunde aus Limburg-Eschhofen. In: S. Schade-Lindig, ed. *Archäologie am Greifenberg bei Limburg an der Lahn: Spuren von der Jungsteinzeit bis zur Römischen Republik*. Darmstadt: Theiss, pp. 170–190.
- KREUZ, A., and SCHÄFER, E., 2002. A new archaeobotanical database programme. *Vegetation History and Archaeobotany*, 11(1–2), 177–179.
- KREUZ, A., and STIKA, H., 2009. Bericht zur archäobotanischen Untersuchung der pflanzlichen Großreste der Fundstelle AK15 Groß-Gerau, „Auf Esch“. *Frankfurter Archäologische Schriften*, 9, 312–338.
- KREUZ, A., and WIETHOLD, J., 2010. Archäobotanische Ergebnisse der eisen- und kaiserzeitlichen Siedlung Mardorf 23, Lkr. Marburg-Biedenkopf. Hinweise auf kulturelle Beziehungen nach Süden und Norden. In: E. Jerem, M. Schönfelder, and G. Wieland, eds. *Nord-Süd, Ost-West Kontakte während der Eisenzeit in Europa Akten der Internationalen Tagungen der AG Eisenzeit in Hamburg und Sopron 2002*. Budapest: Archaeolingua, pp. 151–163.
- LIVARDA, A., 2011. Spicing up life in northwestern Europe. Exotic food plant imports in the Roman and medieval world. *Vegetation History and Archaeobotany*, 20(2), 143–164.
- LODWICK, L., CAMPBELL, G., CROSBY, V., and MÜLDNER, G., 2021. Isotopic Evidence for Changes in Cereal Production Strategies in Iron Age and Roman Britain. *Environmental Archaeology*, 26, 13–28.
- MÄRKLE, T., and FISCHER, E., 2009. Botanische Untersuchungen. In: A. Hensen, ed. *Das römische Brand- und Körpergräberfeld von Heidelberg*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg, 108, Stuttgart: Konrad Theiss Verlag, pp. 91–98.
- MAIER, S., 1988. Botanische Untersuchung römerzeitlicher Pflanzenreste aus dem Brunnen der römischen Zivilsiedlung Köngen Lkr. Esslingen. In: H. Küster, ed. *Der prähistorische Mensch und seine Umwelt, Festschrift für Udelgard Körber-Grohne*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg, 31, Stuttgart: Konrad Theiss Verlag, pp. 291–324.
- MARZANO, A., 2022. *Plants, Politics and Empire in Ancient Rome*. Cambridge: University Press.
- OBERDORFER, E., 1970 *Pflanzensoziologische Exkursionsflora für Süddeutschland*. Stuttgart: Ulmer.
- PÄFFGEN, B., 2014. Küche und Keller – Produktion, Vorratshaltung und Konsum in römischer Antike und Frühmittelalter. Einleitende Bemerkungen zum Tagungsthema. In: Drauschke, J., Prien, R., and Reis, A., eds. *Küche und Keller in Antike und Frühmittelalter*. Tagungsbeiträge der Arbeitsgemeinschaft Spätantike und Frühmittelalter, 7, Hamburg: Dr. Kovac, pp. 3–57.
- PARK, C., ALLABY and M., 2017. *A Dictionary of Environment and Conservation*. 3<sup>rd</sup> ed. Oxford: Oxford University Press.
- PIENING, U., 1982. Botanische Untersuchungen an verkohlten Pflanzenresten aus Nordwürttemberg. *Fundberichte aus Baden-Württemberg*, 7, 239–271.
- PIENING, U., 1986. Verkohlte pflanzliche Beigaben aus einem frühromischen Grabhügel bei Büchel, Kreis Cochem-Zell. *Trierer Zeitschrift*, 49, 257–271.
- PIENING, U., 1988. Verkohlte Pflanzenreste aus zwei römischen Gutshöfen bei Bad Dürkheim Pfalz. In: H. Küster, ed. *Der prähistorische Mensch und seine Umwelt, Festschrift für Udelgard Körber-Grohne*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg, 31, Stuttgart: Konrad Theiss Verlag, pp. 325–340.
- POLLMANN, B., and JACOMET, S., 2012. First evidence of *Mespilus germanica* L. medlar in Roman Switzerland. *Vegetation History and Archaeobotany*, 21, 61–68.
- POSCHLOD, P., 2017. *Geschichte der Kulturlandschaft*. Stuttgart: Ulmer.
- PLINIUS, SG d. Ä., 1995. Naturkunde. Lateinisch-deutsch. In: R. König, ed. *Botanik: Landwirtschaft, Band 15, Buch 18*. Tusculum collection, München: Artemis Publishing House, pp. 87–109.
- PÜHLER, D., 1990. *Die botanischen Makroreste der römischen Zivilsiedlung in Walheim am Neckar 2. Jh. n. Chr.* Unpublished thesis (MA), Hohenheim University.
- REICHEL, D.S., 2002. *Archäobotanische Untersuchungen an römerzeitlichen Pflanzenresten aus Bad Rappenau und Babstadt, Kreis Heilbronn*. Unpublished Thesis (MA), Hohenheim University.
- RODGERS, R.H., 2010. *L. Iuni Moderati Columellae Res rustica. Incerti auctoris Liber de arboribus*. Oxford: Clarendon Press.
- RÖSCH, M., 1989. Botanische Funde aus römischen Brunnen in Murrhardt, RemsMurrkreis. *Archäologische Ausgrabungen in Baden-Württemberg*, 1988, 114–118.
- RÖSCH, M., 1991. Pflanzenreste aus römischer Zeit von Sontheim/Brenz, Kreis Heidenheim. *Archäologische Ausgrabungen in Baden-Württemberg*, 1990, 162–165.
- RÖSCH, M., 1992. Human impact as registered in the pollen record: some results from the western Lake Constance region, Southern Germany. *Vegetation History and Archaeobotany*, 1, 101–109.
- RÖSCH, M., 1993. Zum Ackerbau der Urnenfelderkultur am nördlichen Oberrhein. Botanische Untersuchungen am Fundplatz WieslochWeinacker, RheinNeckarKreis. *Archäologische Ausgrabungen in Baden-Württemberg*, 1992, 95–99.
- RÖSCH, M., 1995. Römische Brunnen in Lahr – Fundgruben für die Botanik. *Archäologische Ausgrabungen in Baden-Württemberg*, 1994, 151–156.
- RÖSCH, M., 2005. Pflanzenreste aus dem römischen Vicus von Güglingen, Steinacker, Kreis Heilbronn. *Archäologische Ausgrabungen in Baden-Württemberg*, 2004, 168–171.
- RÖSCH, M., 2009a. Pflanzenreste. In: B. Schmidt, ed. *Archäologische Untersuchungen im Stadtgebiet von Mengen, Kreis Sigmaringen, Tal Josaphat*. Forschungen und Berichte der Archäologie des Mittelalters in Baden-Württemberg, 27, Stuttgart: Konrad Theiss Verlag, pp. 136–142.
- RÖSCH, M., 2009b. Der Inhalt eines horreums von Bad Rappenau, Kreis Heilbronn. In: J. Biel, J. Heiligmann, and D. Krausse, eds. *Landesarchäologie, Festschrift für Dieter Planck*. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg, 100, Stuttgart: Konrad Theiss Verlag, pp. 379–392.
- RÖSCH, M., 2012. Pflanzenreste im römischen Heidelberg. In: P. Mayer-Reppert, ed. *Jupiter im Brunnen – Archäologische Untersuchungen im Nordvicus von Heidelberg*. Fundberichte aus Baden-Württemberg, 32(2), Stuttgart: Konrad Theiss Verlag, pp. 87–95.
- RÖSCH, M., 2013. Roggen, Hafer, Hülsenfrüchte. Römische und mittelalterliche Pflanzenreste der Ausgrabungen im Sanierungsgebiet Dürrmenz. *Archäologische Ausgrabungen Baden-Württemberg*, 2012, 253–254.
- RÖSCH, M., 2016. Weinbau am Bodensee im Spiegel der Rebpollen. In: T. Knubben, and A. Schmauder, eds. *Seewein – Weinkultur am Bodensee*. Ostfildern: Thorbecke, pp. 51–59.
- RÖSCH, M., 2018. Allerlei Gutes aus Garten und Feld: Zur pflanzlichen Ernährung im römischen Vicus von Lahr-Dinglingen. In: A. Bräuning, and A. Heising, eds. *Entlang der Fernstraße – Die römische Siedlung von Lahr-Dinglingen*. Archäologische Informationen aus Baden-Württemberg, 80, Stuttgart: Landesamt für Denkmalpflege, 116–133.
- RÖSCH, M., 2021. Food production and consumption at Iron Age central places in southern Germany in comparison with rural sites. In: P. Brun, B. Chaume, and F. Sacchetti, eds. *Vix et le phénomène princier. Actes du colloque de Châtillon-sur-Seine 2016*. Pessac: Ausonius Éditions, pp. 269–282.
- RÖSCH, M., BIESTER, H., BOGENRIEDER, A., ECKMEIER, E.,



- EHRMANN, O., GERLACH, R., HALL, M., HARTKOPF-FRÖDER, C., HERRMANN, L., KURY, B., LECHTERBECK, J., SCHIER, W., and SCHULZ, E., 2017. Late Neolithic Agriculture in Temperate Europe – A Long-Term Experimental Approach. *Land*, 6(1), 11. DOI: 10.3390/land6010011
- RÖSCH, M., FISCHER, E., and KURY, B., 2018. Die Maulbronner Klosterweiher – Spiegel von vier Jahrtausenden Kulturlandschaftsgeschichte. *Denkmalpflege in Baden-Württemberg – Nachrichtenblatt der Landesdenkmalpflege*, 46(4), 282–287.
- RÖSCH, M., JACOMET, S., and KARG, S., 1992. The history of cereals in the region of the former Duchy of Swabia Herzogtum Schwaben from the Roman to the Postmedieval period: results of archaeobotanical research. *Vegetation History and Archaeobotany*, 1, 193–231.
- RÖSCH, M., and LECHTERBECK, J., in press. Zur spät- und nacheiszeitlichen Vegetations- und Landnutzungsgeschichte des Hegau. *Fundberichte aus Baden-Württemberg*, 41.
- RÖSCH, M., and MARINOVA, E., 2020. Zeller See. *Grana* 60(3), 243–245.
- RÖSCH, M., and RAPP, M., 2019. Getreide und Ackerwildkräuter aus dem Gutshof von Enzberg, Schellenäcker zur Kenntnis des römischen Ackerbaus. In: J. Klotz, and E. Freiburger, eds. *Die Römer in Mühlacker, 20 Jahre Historisch-Archäologischer Verein Mühlacker HAV*. Bauschlott: Remchingen, pp. 56–59.
- RÖSCH, M., STOJAKOWITS, P., and FRIEDMANN, A., 2021. Does site elevation determine the start and intensity of human impact? Pollen evidence from southern Germany. *Vegetation History and Archaeobotany*, 30, 255–268.
- RÖSCH, M., and TSERENDORJ, G., 2011. Der Nordschwarzwald – früher besiedelt als gedacht? Pollenprofile belegen ausgedehnte vorgeschichtliche Besiedlung und Landnutzung. *Denkmalpflege in Baden-Württemberg*, 40(2), 66–73.
- SCHULZE, E., 2014. *Deutsche Agrargeschichte: 7500 Jahre Landwirtschaft in Deutschland*. Aachen: Shaker.
- STIKA, H.-P., 1996. *Römerzeitliche Pflanzenreste aus Baden-Württemberg*. Materialhefte zur Archäologie, 36, Stuttgart: Konrad Theiss Verlag.
- TRIXL, S., STEIDL, B., and PETERS, J., 2017. Archaeology and Zooarchaeology of the Late Iron Age – Roman Transition in the Province of Raetia 100 BC–100 AD. *European Journal Archaeology*, 20(3), 431–450.
- TSERENDORJ, G., MARINOVA, E., LECHTERBECK, J., BEHLING, H., WICK, L., FISCHER, E., SILLMANN, M., MÄRKLE, T., and RÖSCH, M., 2021. Intensification of agriculture in southwestern Germany between the Bronze Age and Medieval period, based on archaeobotanical data from Baden-Württemberg. *Vegetation History and Archaeobotany*, 30, 35–46.
- VAN DER VEEN, M., 2007. Formation processes of desiccated and carbonized plant remains – the identification of routine practice. *Journal of Archaeological Science*, 34, 968–990.
- VAN DER VEEN, M., LIVARDA, A., and HILL, A., 2008. New Plant Foods in Roman Britain — Dispersal and Social Access. *Environmental Archaeology*, 13, 11–36.
- VANDORPE, P., 2010. *Plant macro remains from the 1<sup>st</sup> and 2<sup>nd</sup> Century A.D. in Roman Oedenburg / Biesheim-Kunheim F. Methodological aspects and insights into local nutrition, agricultural practises, import and the natural environment*. Unpublished thesis (PhD), Basel University.
- WIETHOLD, J., 2012. Hirse, Hanf und Hohl-dotter – Pflanzenfunde aus einem römischen Brunnen in Otterbach, Kr. Kaiserslautern. In: A. Stobbe, and U. Tegtmeier, eds. *Verzweigungen. Eine Würdigung für A. J. Kalis und J. Meurers-Balke*, Frankfurter Archäologische Schriften, 18, Bonn: R. Habelt, pp. 311–323.
- ZACH, B., 2002. Vegetable offerings on the Roman sacrificial site in Mainz, Germany – short report on the first results. *Vegetation History and Archaeobotany*, 11, 101–106.

