Volume XV ● Issue 2/2024 ● Online First

INTERDISCIPLINARIA ARCHAEOLOGICA
NATURAL SCIENCES IN ARCHAEOLOGY

homepage: http://www.iansa.eu

"Cui Bono?" An Agricultural Turning Point in the Roman Provinces Upper Germania and Raetia

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A R T I C L E I N F O

Article history:
Received: 11th July 2023
Accepted: 11th June 2024

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

Key words:
agricultural intensification
archaeobotany
pollen analysis
plant macrofossils
southwestern Germany

A B S T R A C T

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 Older, 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; Päffgen, 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

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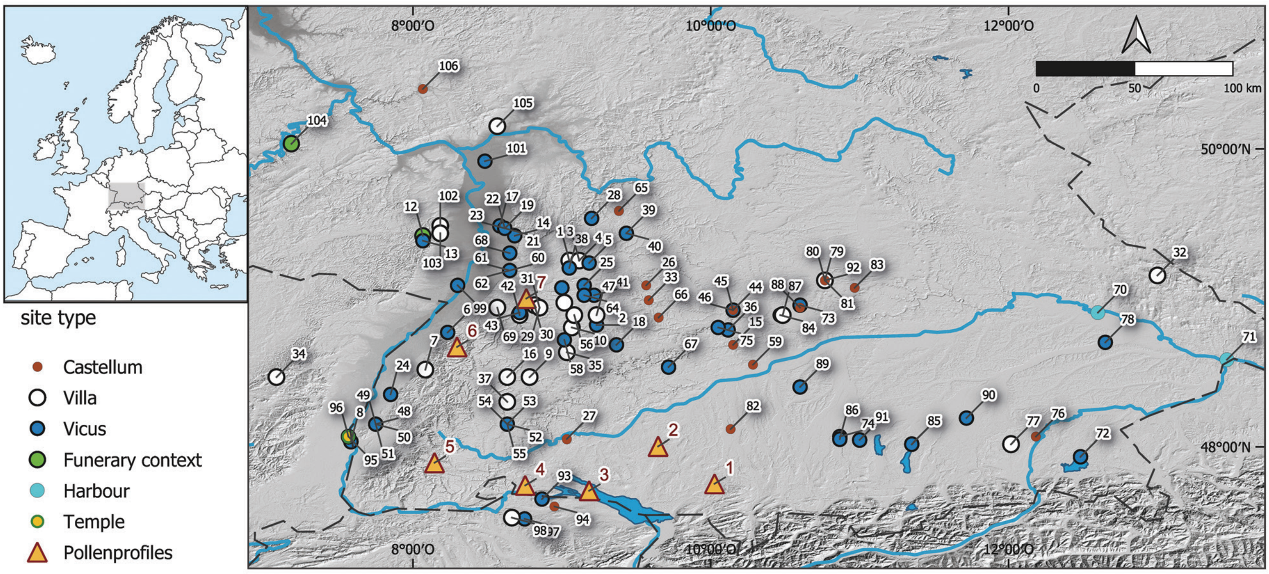


Figure 1. Map with archaeological sites marked by circles (numeration given in Table 1) and pollen sites marked by a red bordered triangle: 1. Großer Ursee (Rösch *et al.*, 2021), 2. Zellsee (Rösch and Marinova, 2020) 3. Mainau (Rösch and Wick, 2018), 4. Hartsee (Rösch and Lechterbeck, in press), 5. 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 (Poschlod, 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 5th 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

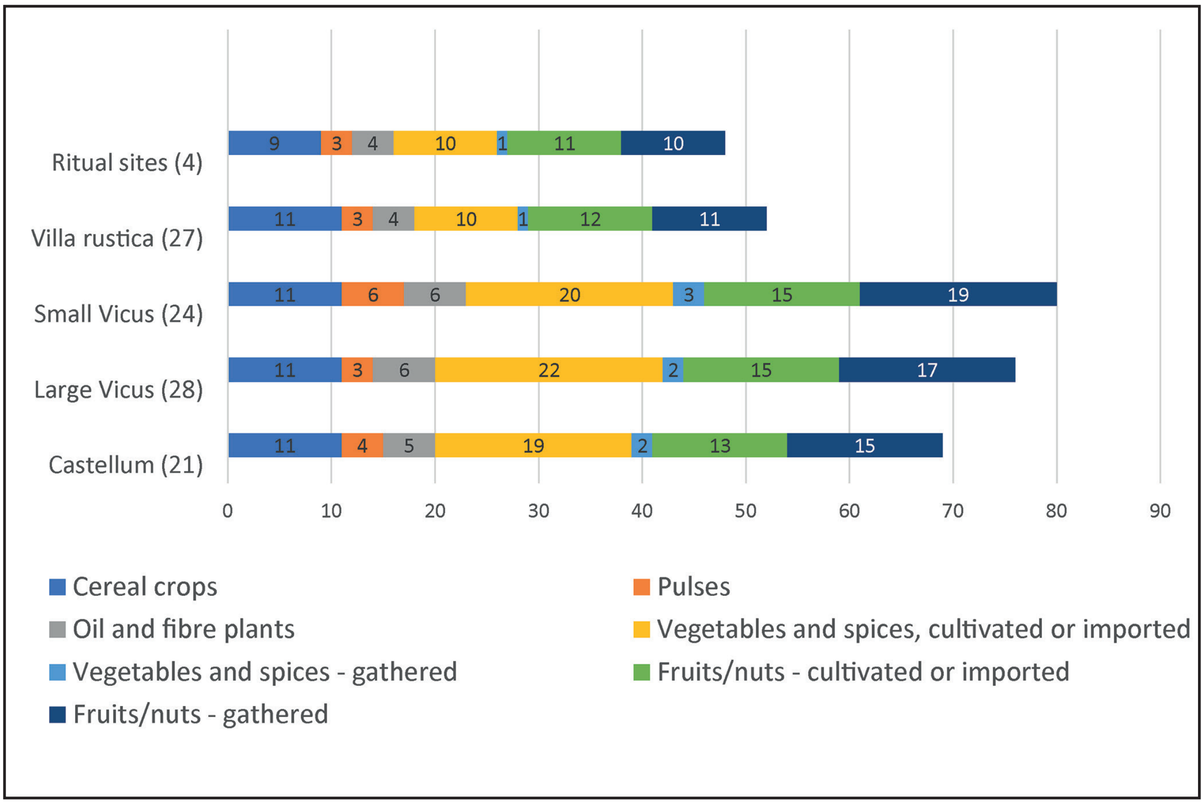


Figure 2. Crop diversity per site (n=106) types.

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
Baden-Württemberg												
1	Babstadt	49°15' N	9°03' E	248	*Villa*		well, granary	2	19	72.15		Reichle, 2002
2	Bad Cannstatt- Stuttgart	48°49' N	9°14' E	243	*Vicus*	large	cellar	4	10	12.36	w	Marinova *et al.*, 2019
3	Bad Rappenau	49°15' N	9°07' E	227	*Villa*		granary	3	6	8.95		Rösch, 2009b
4	Bad Rappenau	49°15' N	9°07' E	227	*Villa*		granary	1	1			Reichle, 2002
5	Bad Wimpfen im Tal	49°14' N	9°11' E	148	*Vicus*		well	38	38		w	Fröschle, in print
6	Baden-Baden	48°46' N	8°14' E	161	*Vicus*	large	divers	21	42		w	Stika, 1996
7	Bondorf	48°31' N	8°50' E	458	*Villa*		cultural layer	2	2			Körber-Grohne and Piening, 1979
8	Breisach	48°02' N	7°35' E	191	*Vicus*	large	pit	1	1			Lab.Arbo.unpub.
9	Eutingen im Gäu, Rohrdorf	48°28' N	8°47' E	479	*Villa*		pit	1	1	2.5		Lab.Arbo.unpub.
10	Gerlingen	48°48' N	9°04' E	333	*Villa*		cellar		12			Lab.Arbo.unpub.
11	Güglingen	49°04' N	9°00' E	205	*Vicus*	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	*Vicus*	large	divers	4	4	15.4		Lab.Arbo.unpub.
14	Heidelberg-Neuenheim	49°25' N	8°41' E	112	*Vicus*	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	*Villa*		pits	1	1			Lab.Arbo.unpub.
17	Ilvesheim	49°29' N	8°35' E	97	*Vicus*	small?	pits, ditches	2	7	130.43		Lab.Arbo.unpub.
18	Köngen	48°41' N	9°22' E	331	*Vicus*	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	*Vicus*	large	pits, cultural layer	2	5	25.05		Lab.Arbo.unpub.
21	Ladenburg	49°28' N	8°37' E	105	*Vicus*	large	well, grave	3	4	19.26	w	Lab.Arbo.unpub.
22	Ladenburg	49°28' N	8°37' E	105	*Vicus*	large	well	2	2	21.5	w	Lab.Arbo.unpub.
23	Ladenburg	49°28' N	8°37' E	105	*Vicus*	large	latrine	6	7	6.81	w	U. Maier
24	Lahr-Dinglingen	48°21' N	7°51' E	159	*Vicus*	small	wells, pits	14	14	19.03	w	Rösch, 1995, 2018
25	Lauffen	49°05' N	9°09' E	175	*Villa*		cellar	1	1			Piening 1982
26	Mainhardt	49°05' N	9°34' E	484	Fort/*Vicus*	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	*Vicus*	small	pits, cultural layer					Lab.Arbo.unpub.
29	Mühlacker-Dürrmenz	48°56' N	8°51' E	222	*Vicus*	small	graves, pits, sunken huts	1	1	5.5		Rösch, 2013
30	Mühlacker-Enzberg	48°57' N	8°49' E	228	*Villa*		pits and others	5	21	16		Rösch and Rapp, 2019
31	Mühlacker-Lomersheim	48°56' N	8°51' E	219	*Villa*		cellar	8	8	0.39		Hugonot *et al.*, 1991
32	Mundelsheim	49°00' N	9°13' E	202	*Villa*		well		7		w	Stika, 1996
33	Murrhardt	48°59' N	9°35' E	288	Fort/*Vicus*		well	3	3		w	Rösch, 1989, Lab.Arbo.unpubl.
34	Neuried-Müllen	48°28' N	7°50' E	146	*Villa*		well	4	4	4.17		Lab.Arbo.unpub.
35	Nürtingen	48°38' N	9°20' E	273	*Villa*		cellar					Stika, 1996
36	Oberkochen	48°47' N	10°07' E	487	*Vicus*		cellar	1	1			Piening, 1982
37	Oberndorf-Bochingen	48°18' N	8°38' E	571	*Villa*		divers	6	8	4.92		Lab.Arbo.unpub.
38	Öhringen	49°12' N	9°30' E	230	*Vicus*	large	SoBefu	1	4			Lab.Arbo.unpub.
39	Osterburken	49°26' N	9°26' E	266	Temple		well	1	37	9.25	w	Fröschle, 1994
40	Osterburken	49°26' N	9°26' E	266	*Vicus*		cultural layer	1	5	7.65		Lab.Arbo.unpub.
41	Ottmarsheim	49°01' N	9°13' E	327	*Vicus*		pits	4	4	9.6		Lab.Arbo.unpub.
42	Pforzheim, Städt. Krankenhaus	48°53' N	8°43' E	251	*Villa*		wells, pits	7			w	Fietz, 1961
43	Pforzheim-Kappelhof	48°54' N	8°43' E	251	*Vicus*	large	well and others	13	39	41.93	w	Lab.Arbo.unpub.
44	Rainau-Buch	48°55' N	10°09' E	465	Fort/*Vicus*	small	well				w	Stika, 1996
45	Rainau-Buch	48°55' N	10°09' E	465	*Vicus*	small	pits, cellar	11	12			Lab.Arbo.unpub.
46	Rainau-Buch	48°55' N	10°09' E	465	Fort/*Vicus*							Piening, 1982
47	Remseck-Aldingen	48°53' N	9°14' E	272	*Villa*		cellar	1	1			Lab.Arbo.unpub.
48	Riegel	48°09' N	7°45' E	185	*Vicus*		latrine	8	12	18.3	w	Lab.Arbo.unpub.
49	Riegel	48°09' N	7°45' E	185	*Vicus*	small	pit, latrine	4	5	37.1	w	Lab.Arbo.unpub.
50	Riegel	48°09' N	7°45' E	185	*Vicus*							Lab.Arbo.unpub.
51	Riegel, Fronhofbuck	48°09' N	7°45' E	185	*Vicus*	small?	well		4		w	Stika, 1996
52	Rottweil	48°09' N	8°38' E	590	*Vicus*	large	well	1			w	Baas, 1974
53	Rottweil, Hochmauren	48°09' N	8°38' E	590	*Vicus*	large	pit	1				Stika, 1996
54	Rottweil, Steinwandel	48°09' N	8°38' E	590	*Vicus*	large	well	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	*Vicus*	large	bustum	1	1	1		Lab.Arbo.unpub.
56	Schwieberdingen	48°53' N	9°05' E	275	*Villa*		pit	6	7	30.22		Lab.Arbo.unpub.
57	Sersheim	48°58' N	9°01' E	215	*Villa*		pit, cellar	1	1	0.76		Lab.Arbo.unpub.
58	Sindelfingen	48°43' N	9°01' E	433	*Vicus*	small	well				w	Stika, 1996
59	Sontheim/Brenz	48°33' N	10°17' E	446	Fort		well	10	12	11.67	w	Rösch, 1991
60	Stettfeld, Mühlberg	49°11' N	8°39' E	119	*Vicus*	large	well	1	1		w	Stika, 1996
61	Stettfeld	49°11' N	8°39' E	119	*Vicus*	large	well, kiln	21	39	199	w	Lab.Arbo.unpub.
62	Stettfeld, Marcellusplatz	49°11' N	8°39' E	119	*Vicus*	large	cellar	1	1			Stika, 1996
63	Stettfeld, Talstr.	49°11' N	8°39' E	119	*Vicus*	large	well	3	3		w	Stika, 1996
64	Walheim	49°01' N	9°09' E	183	*Vicus*						w	Pühler, 1990
65	Walldürn, Am Römerbad	49°35' N	9°23' E	400	Fort/*Vicus*	small	cellar	10	10			Stika, 1996
66	Welzheim Ostkastell	48°52' N	9°39' E	495	Fort		wells, pits	4	15		w	Körber-Grohne *et al.*, 1983
67	Widderstall-Mittelbuchen	48°32' N	9°43' E	751	*Vicus*	small	cultural layer	20	36	140		Lab.Arbo.unpub.
68	Wiesloch	49°18' N	8°39' E	106	*Vicus*	large?	pits	1	1	0.12		Rösch, 1993
69	Wilferdingen	48°56' N	8°34' E	162	*Villa*		cultural layer	1	1	2100		Lab.Arbo.unpub.
Bayern												
70	Straubing-Azlburg	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	Seebruck	47°56' N	12°29' E	526	*Vicus*	large		8				Küster, 1995
73	Oettingen	48°57' N	10°36' E	419	*Vicus*	large		2				Küster, 1995
74	Oberndorf	48°40' N	10°52' E	407	*Vicus*	large		2				Küster, 1995
75	Großsorheim	48°48' N	10°30' E	447	*Vicus*	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	*Villa*			1				Küster, 1995
78	Pilsting	48°42' N	12°39' E	341	*Vicus*	small		5				Küster, 1995
79	Weißenburg-Gunzenhausen	49°07' N	10°46' E	421	*Villa*			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/*Vicus*	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.
Schweiz, Frankreich												
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
Rheinland-Pfalz, Hessen												
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 (~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 (~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.

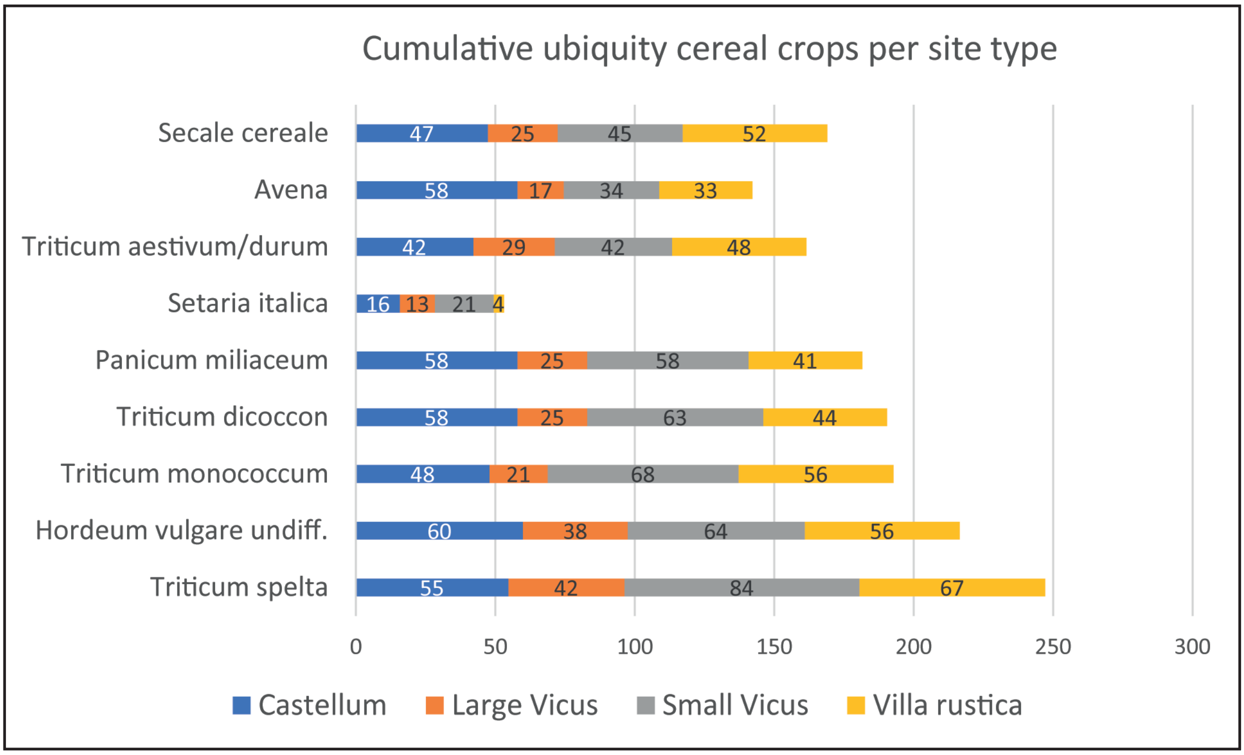
3.1.2 Tillage intensity of the arable fields

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



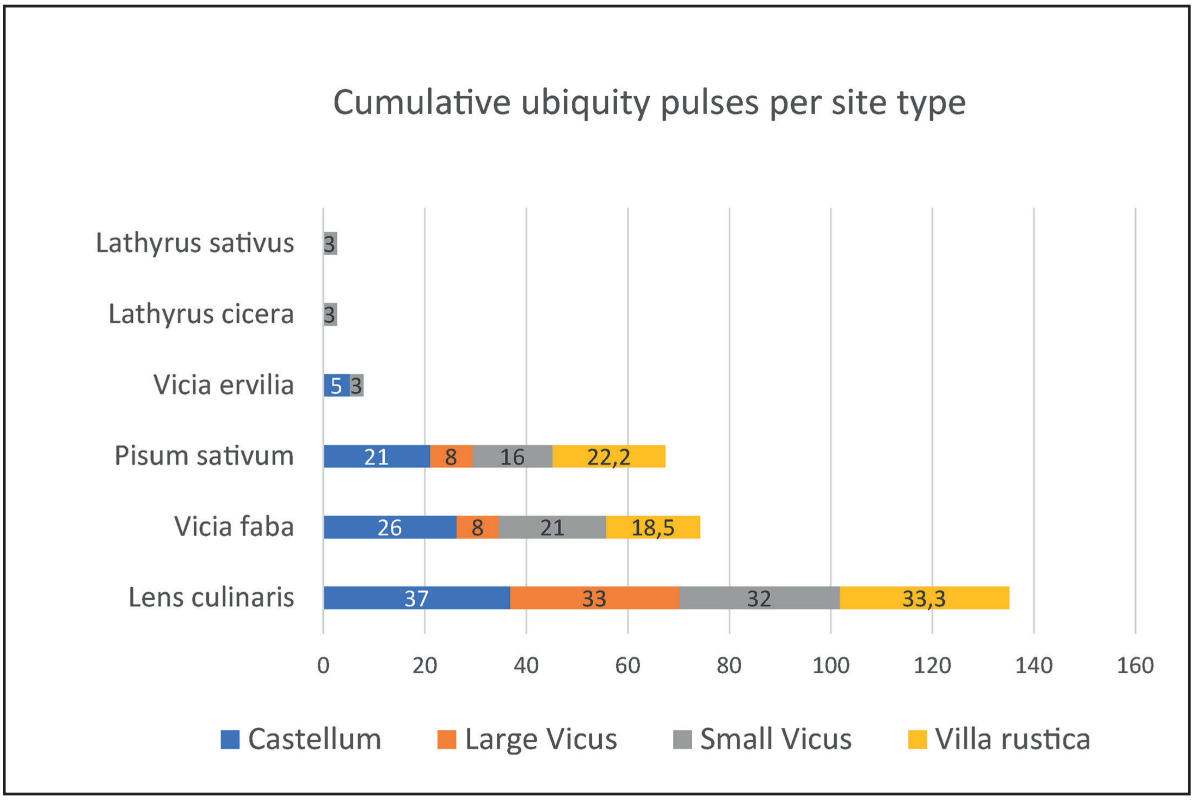


Figure 3. Site-based (n=106) ubiquity: A. of cereals (up); B. vegetables and spices (down).

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

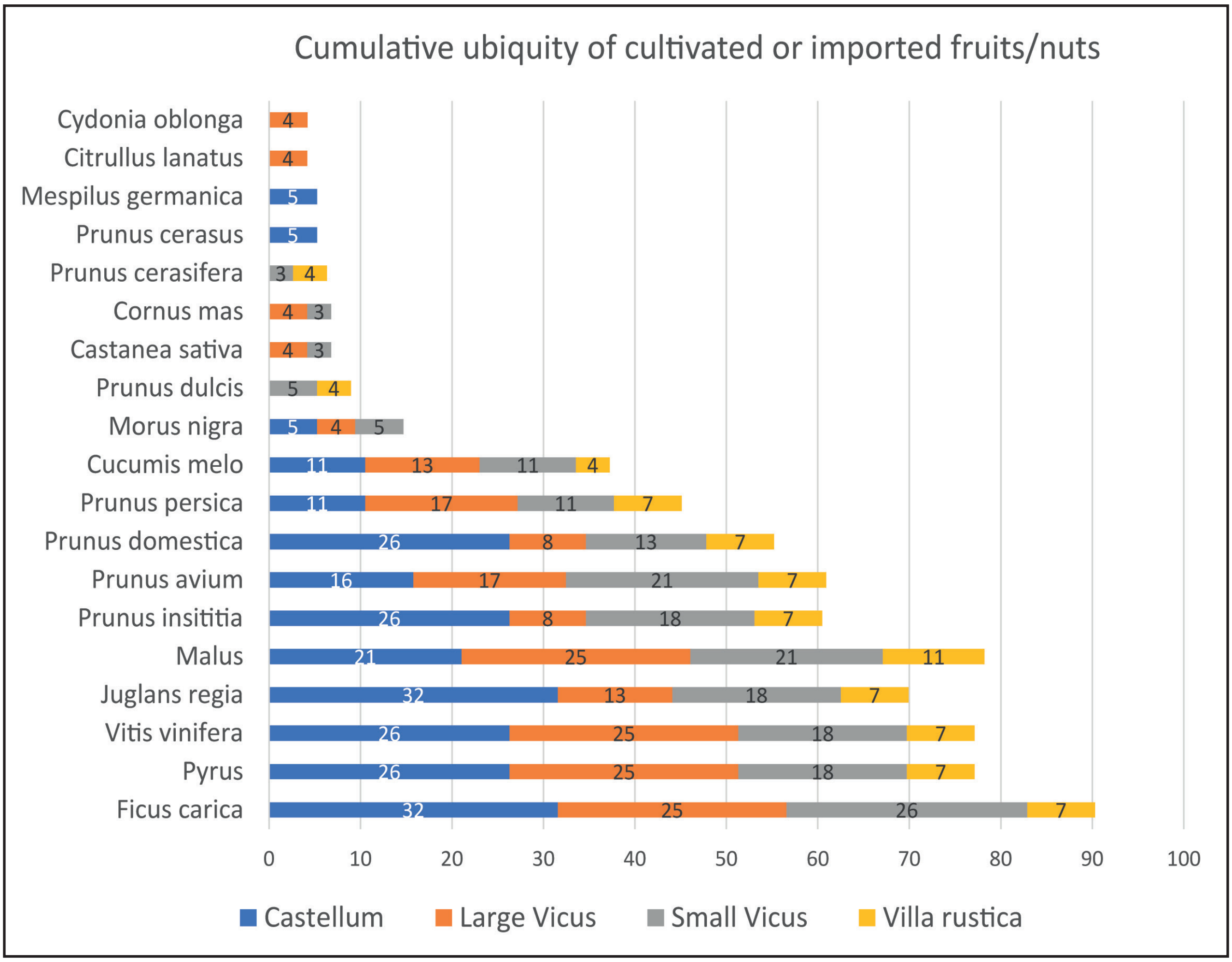


Figure 3. Site-based (n=106) ubiquity: C. cultivated fruits.

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,

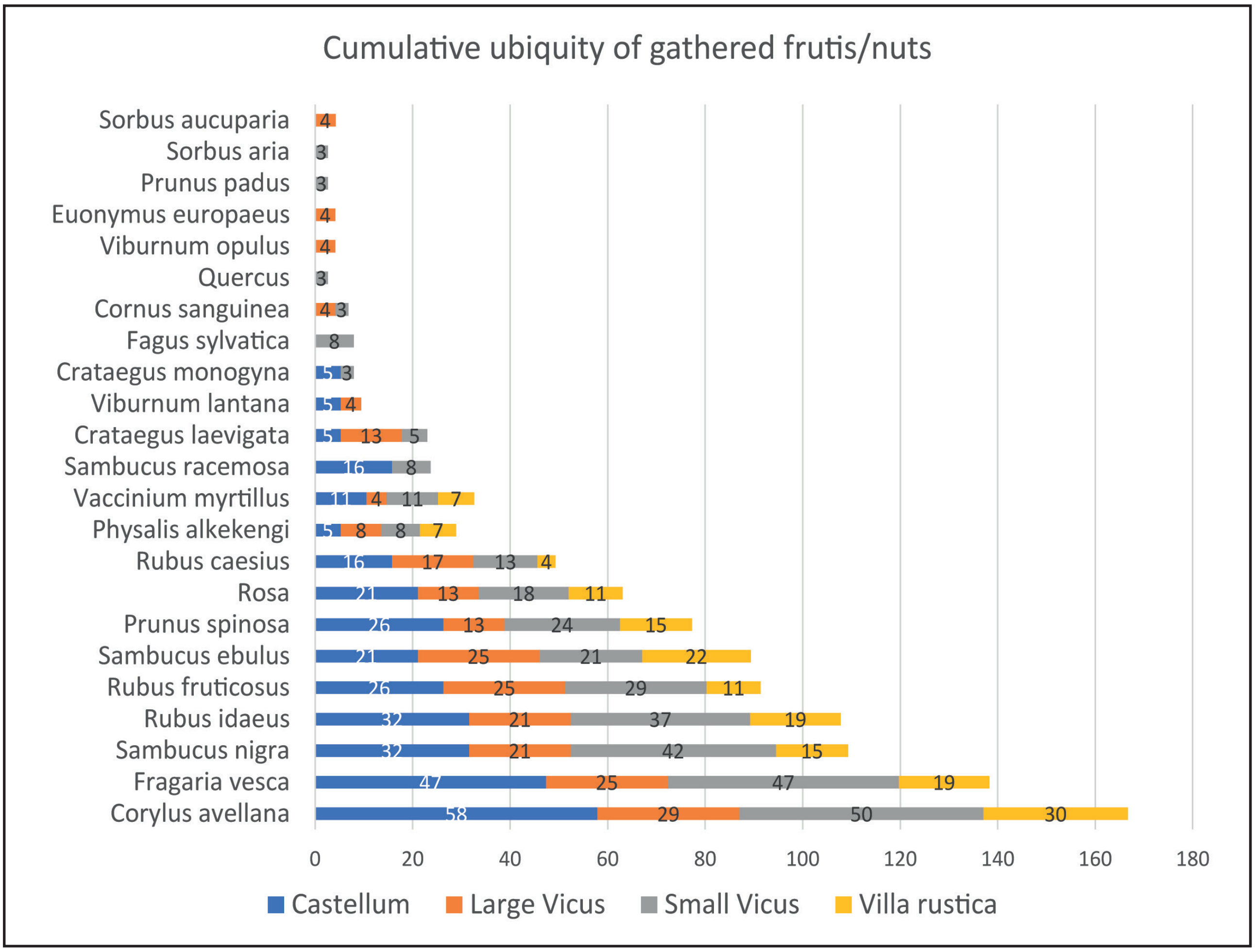


Figure 3. Site-based (n=106) ubiquity: D. gathered fruits.

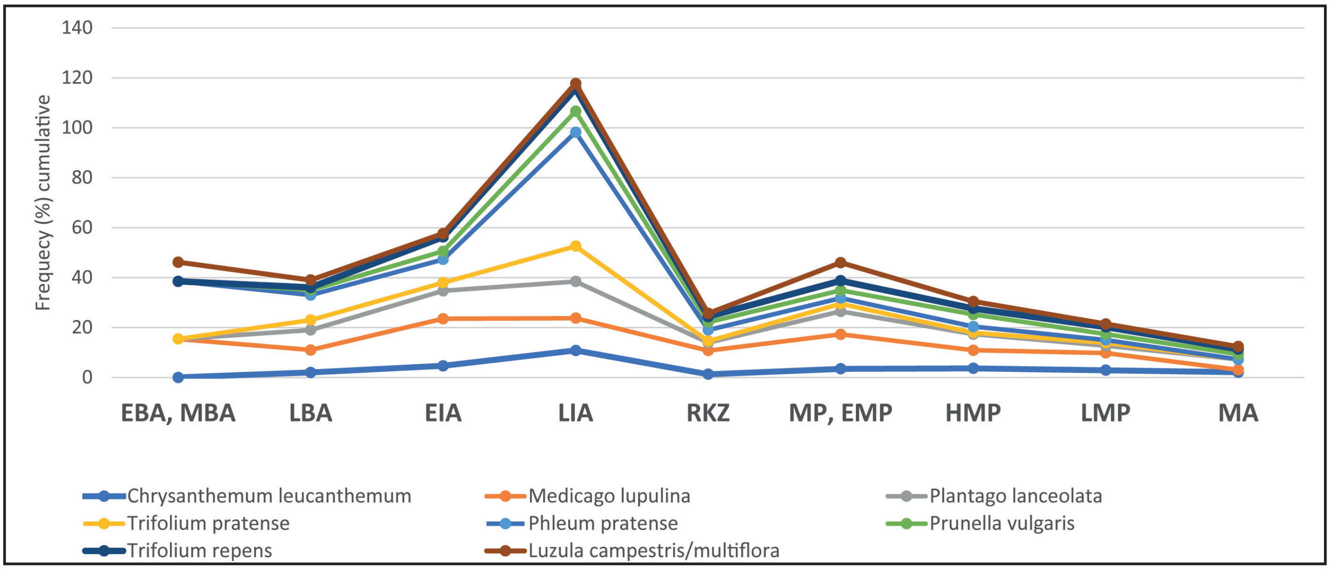


Figure 4. Feature-based ubiquity for charred remains from 248 archaeological sites of grassland plants for Bronze Age to Early Modern Times (*Trifolium repens, Prunella vulgaris, Phleum pratense*, *Trifolium pratense, Chrysanthemum leucanthemum, Plantago lanceolata*). Abbreviations: EBA/MBA: Early Bronze 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.

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

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

	Castellum	**Large *Vicus***	**Small *Vicus***	***Villa rustica***
Cucumis melo	11	13	11	4
Morus nigra	5	4	5	
Prunus dulcis			5	4
Castanea sativa		4	3	
Cornus mas		4	3	
Prunus cerasifera			3	4
Prunus cerasus	5			
Mespilus germanica	5			
Citrullus lanatus		4		
Cydonia oblonga		4		
Phoenix dactylifera				
Pinus pinea				
Fruits and nuts, gathered				
Corylus avellana	58	29	50	30
Fragaria vesca	47	25	47	19
Sambucus nigra	32	21	42	15
Rubus idaeus	32	21	37	19
Rubus fruticosus	26	25	29	11

	Castellum	**Large *Vicus***	**Small *Vicus***	***Villa rustica***
Sambucus ebulus	21	25	21	22
Prunus spinosa	26	13	24	15
Rosa	21	13	18	11
Rubus caesius	16	17	13	4
Physalis alkekengi	5	8	8	7
Vaccinium myrtillus	11	4	11	7
Sambucus racemosa	16		8	
Crataegus laevigata	5	13	5	
Viburnum lantana	5	4		
Crataegus monogyna	5		3	
Fagus sylvatica			8	
Cornus sanguinea		4	3	
Quercus			3	
Viburnum opulus		4		
Euonymus europaeus		4		
Prunus padus			3	
Sorbus aria			3	
Sorbus aucuparia		4		

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

Period	**Iron Age**	**Roman**	**Migration Period**
Cereals			
Avena	X	X	X
Hordeum distichon	–	–	X
Hordeum vulgare	X	X	–
Hordeum vulgare undiff.	X	X	X
Panicum miliaceum	X	X	X
Secale cereale	X	X	X
Setaria italica	X	X	X
Triticum aestivum/durum	X	X	X
Triticum cf. timophevii	X	–	–
Triticum dicoccon	X	X	X
Triticum monococcum	X	X	X
Triticum spelta	X	X	X

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

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,

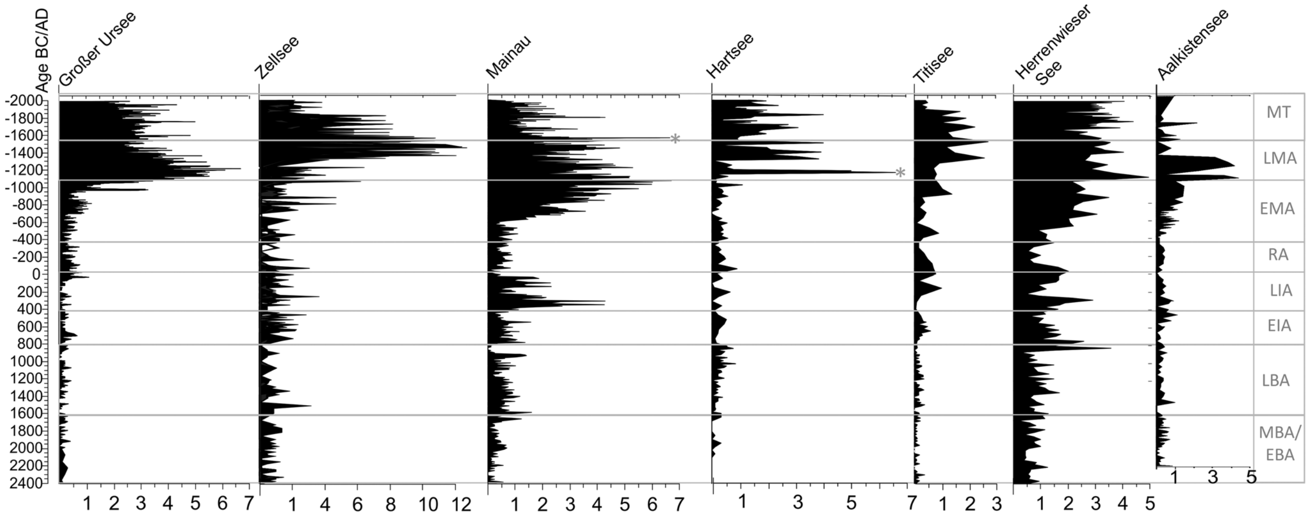


Figure 5. Indicators for woodland pasture expressed as sum curve per site. Pollen types considered *Juniperus communis, Melampyrum, Calluna vulgaris, Pteridium aquilinum, Genista* type., *Ilex aquifolium, Cytisus,* and *Polypodium vulgare*. Percentages based on the terrestrial pollen sum.

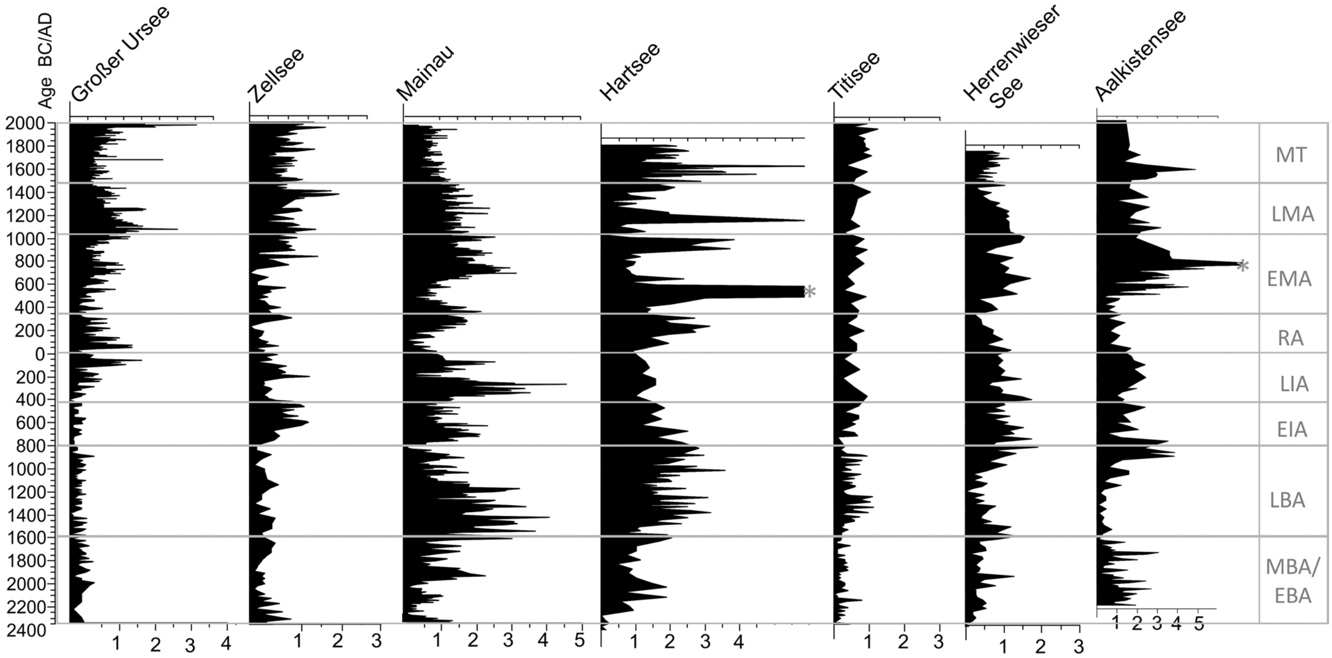


Figure 6. Indicators for ruderal communities in the considered pollen profiles, expressed as sum curve per site. Pollen types considered: *Artemisia, Urtica, Chenopodiaceae, Plantago major, Sambucus nigra/racemosa, Daucus carota, Chaerophyllum hirsutum* type, *Sambucus ebulus, Aegopodium podagraria, 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 1st 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 $\delta^{15}N$ 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.

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