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DISCUSSION

Botanical off-site and on-site data as indicators of different land use systems: a discussion with examples from Southwest Germany

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Abstract Off-site pollen data as well as onsite plant macrofossil data from Southwest Germany enable the distinguishing of three main phases of agricultural land use history. The last phase, here simplified called the "Extensive ard phase", had already started in the Bronze Age and ends in the 19th century A.D. It is characterized by extensive land management, permanent fields with short fallow phases, ploughing, the use of animal dung as fertilizer, and grazed woodlands. The first phase, comprising the Old and Middle Neolithic, is characterized by hoe-farming only on very fertile soils and a very restricted set of crops. For the second phase, comprising the Young, Late and Final Neolithic, a slash-and-burn-like agricultural system is most probable. During the Late and Final Neolithic, this cultivation system with fire use and shifting fields was gradually practised on permanent fields and was modified, leading finally to the "Extensive ard" land use system with fertilizer and ploughing instead of burning.

Keywords Land use systems · Prehistory · Temperate Europe · Pollen data · Plant macrofossil data

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Introduction

Old World agriculture originates from the Near East (e.g. Asouti and Fuller 2012; Riehl et al. 2012; Willcox 2007; Willcox et al. 2012; Zohary et al. 2012). When crops and animals were domesticated in this region towards the end of the last glacial or shortly afterwards, the climate was even more arid than today, and the plants cultivated were steppe plants, unable to grow under a dense tree canopy (Bottema 2002). These founder crops are annuals, for which the ratio of fruits or seeds as the edible parts to the total biomass of the plant is higher than for perennials.

When agriculture was introduced to temperate Europe in the course of the seventh millennium B.C., the landscapes were still totally covered by mostly deciduous woodland (Lang 1994). Crops, annual wild grasses or herbs, growing preferentially together in large numbers of individuals, cannot compete with the indigenous species, especially the trees and shrubs. The crops in particular are pioneer plants, and must be sown on bare ground with light soils and afterwards protected against stronger competitors. As do all plants, they need light, fertile soils and water. In temperate Europe, water is normally a minor problem. Nutrients become a limiting factor as the soils become poorer in nutrients through repeated cultivation-harvest cycles. Often soil acidification is linked to this nutrient loss. Therefore crop rotation, including fallow periods or fertilisation is applied, or a combination of these to avoid such a negative development. In woodlands, the stronger competitors like trees, shrubs and other woodland plants need to be removed before crop cultivation. For a sufficient harvest a number of different measures, carried out at the appropriate times and making up the land use system, are necessary. Different land use systems were possible in the past and were

Table 1 Possible Neolithic land use systems, after Bogaard (2004), modified

System	Tillage	Fertilisation	Fallow phases	Yields	Other requirements	Occurrence
Extensive ard cultivation	Ploughing	Animal dung	Short	Low	Cattle/horses	BA to modern
Floodplain cultivation	Ploughing?	Natural flooding	During flooding	High	Big river valleys	Egypt, others?
Intensive garden cultivation	Hand tillage	?	?	Depends…	Fertile soils	Early Neolithic?
Slash-and-burn cultivation	–	Wood ash	Long	High	Huge forests	Late Neolithic?

perhaps practised in a different way in different periods and regions (Bogaard 2004; Table 1).

The most important sources of information about prehistoric land use are high-resolution pollen diagrams, preferably from sediments from the central part of small lakes. This evidence should be supplemented by on-site botanical macrofossil data whenever possible, at best from sites with wet preservation. For historical times, contemporary written sources can also be used.

Whereas the representation of pollen types as indicators for vegetation is influenced by natural factors, for example pollen productivity and dispersion, basin size and geomorphology, the representation of plant macrofossils in archaeological features is determined by mainly anthropogenic factors such as harvesting, crop processing or even cultural factors like preferences in consumption (Jacomet and Kreuz 1999). Therefore to work out the context of arable vegetation and land use is even more difficult using on-site data.

This contribution compares different agricultural systems of the Early Neolithic, the Young Neolithic and of the High Medieval period, based on on-site and off-site pollen and plant macrofossil evidence from Southwest Germany, focusing on the Lake Constance region. The main aim is to give the reasons behind the Forchtenberg experiment; furthermore the Forchtenberg results support the point of view here presented.

Materials and methods

For the present study a large amount of on-site data from lake-shore sites of the western Lake Constance region, dating between 4000 and 850 cal. B.C. were available and have been used (Rösch 1990, 1996; Maier 1999, 2001; Dieckmann et al. 2006; Billamboz et al. 2010) (Fig. 1). Eight well-dated diagrams with high temporal resolution were chosen from numerous pollen diagrams of the region to allow a deep insight into the development of vegetation, landscape and agriculture during the Neolithic, Bronze and Iron Ages (see also Lechterbeck et al. 2013). Two of these profiles are from the shallow water zone of Lake Constance, one from the centre of a medium-sized lake (Mindelsee), four from the centres of small lakes, and one from a small kettle hole mire, originating from a former lake (Fig. 1; Table 2).

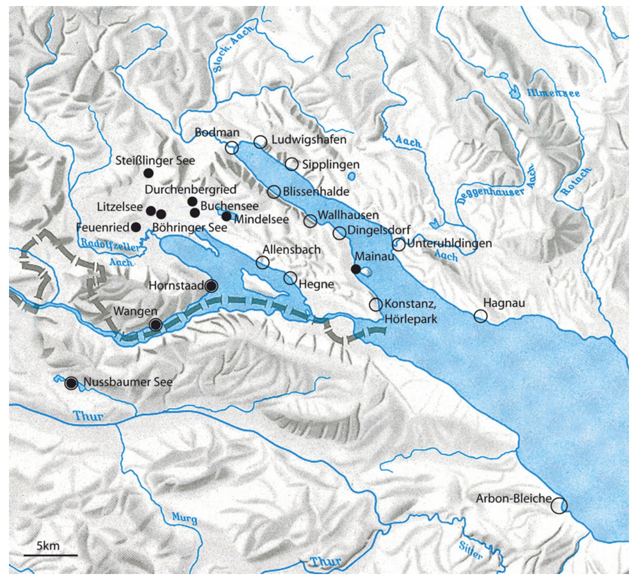


Fig. 1 Botanical off-site and on-site data in the western Lake Constance region *black circle* off-site pollen profile, *white square* archaeological site with archaeobotanical investigation

Most of these pollen diagrams were elaborated by subsampling without gaps between 5000 cal. B.C. and at least 1 cal. B.C./A.D., in some cases until the present. The samples were prepared for pollen analysis following the standard procedure with addition of *Lycopodium* spores, applying hot HCL, KOH, HF, acetolysis and staining in glycerine. The analysis was carried out using permanently mounted slides with glycerine. The pollen sum in each subsample was usually at least 1,000 arboreal pollen grains (AP), but in the earlier analysed profiles Durchenbergried and Hornstaad and in the prehistoric part of Mindelsee the sums were 500–800 AP. Besides pollen and spores, micro-charcoals were registered quantitatively by counting. The time models are based on about 20 radiocarbon dates on average in each profile.

Discussion

Off-site pollen evidence

The results of the on-site as well as off-site studies are partly published (Rösch 1990, 1992, 1993, 1996, 1997,

Table 2 Pollen sites in the Lake Constance region

Site	Latitude E	Longitude N	m a.s.l.	Depth (m, max.)	Area (ha)	Samples	Analyst	Reference
Mainau	9°11′06″	47°42′20″	395	3	5,486[a]	991	L. Wick/M. Rösch	
Mindelsee	9°01′23″	47°45′20″	406	14	99	398	A. Kleinmann/ M.Rösch	Rösch (2013)
Hornstaad/Untersee	9°00′38″	47°41′47″	395	2	5,814[b]	890	M. Rösch	Rösch (1992, 1993, 1997)
Buchensee-Südost	8°59′05″	47°46′00″	429	2	1,2	300	L. Wick	
Durchenbergried	8°58′48″	47°46′34″	432		3	498	M. Rösch	Rösch (1990)
Böhringer See	8°56′18″	47°45′48″	406	8	5,5	219	J. Lechterbeck	
Litzelsee	8°55′50″	47°46′08″	407	8	1,3	460	J. Lechterbeck/ M. Rösch	
Steisslinger See	8°55′02″	47°47′57″	446	18	11,2	220	J. Lechterbeck	Lechterbeck (2001)

[a] Überlinger See

[b] Untersee

2013; Lechterbeck 2001; Lechterbeck et al. 2013) and partly in preparation. The unpublished data we refer to cannot fully be presented in this paper.

The "Extensive ard" land use system

We have good knowledge about the pre-industrial land use systems of temperate Europe in historical times, mostly from written sources (Jänichen 1970; Henning 1994). Most common were permanent, ploughed fields, cultivated with interruptions by short fallow phases including grazing by animals. The fertilizer was manure, composted excrement of domestic animals fixed by organic litter. Because the animals browsed mainly in the landscapes outside the fields, especially in the woodlands, and because the litter was also mostly collected in the woodland, historic agriculture implied an outfield-infield transfer of nutrients. The fields were located on the better soils, the remaining woodlands on the poorer ones. This nutrient transfer accentuated the infield-outfield soil quality gradient (Menke 1995). In the pollen record, there is an example in the diagram from the Mindelsee (Fig. 2). Here this so-called "Extensive ard" system is indicated by high NAP percentages, caused by huge deforested areas, used as fields or pastures, and by relatively open, savannah-like woodlands as a consequence of woodland grazing (Kalis et al. 2003). The latter is also indicated by an increase of *Juniperus* and woodland fires evidenced by microcharcoals, *Pteridium aquilinum*, *Calluna vulgaris* and *Vaccinium*-type, the last three also indicating soil acidification. The coppice-with-standards woodland management practised is indicated by the dominating *Quercus* curve, and coppice woodland management, especially during phases with heavy human impact, by an increase of shrubs and pioneer trees as *Corylus*, *Betula* and *Salix*; whereas the stages with no or weak human impact are indicated by an increase of shadow tolerant trees like *Fagus sylvatica*, *Carpinus betulus* and *Abies alba*. The extension of agriculture even to poor or dry soils during intensive land use phases is indicated by members of the Aphanion and Caucalidion societies in the pollen diagram, such as *Centaurea cyanus*, *Aphanes arvensis*, *Bupleurum rotundifolium*, *Orlaya grandiflora*, *Consolida regalis*, *Adonis aestivalis*, *Caucalis platicarpos*, *Legousia speculum-veneris*, *Kickxia elatine/spurium* and *Scandix pecten-veneris*, as well as *Agrostemma githago* if the data set is big enough, because these entomogamous species are poorly represented in the pollen record (Rösch 2013). The same species are also well known as macrofossils from archaeological features of the medieval period. These signs of "Extensive ard agriculture" can be traced back to the Roman period, the pre-Roman Iron Age and even to the Bronze Age, in the pollen as well as in the macrofossil record, at least in single landscapes such as the Lake Constance region.

The example for the "Extensive ard agriculture" in the western Lake Constance region, the diagram from Mindelsee depicting the vegetation history of the last two millennia, shows the typical synanthropic vegetation of this region (Figs. 1, 2). In comparison with another high-resolution data set of the same period from Central Germany (Beug 2011), from a region with different soils and climate, there is clear proof that even rare pollen types in such high-quality data sets are not random, but can be interpreted in terms of vegetation, environment and land use. For at Maujahn, in a landscape with rather poor and acidic soils, crop weeds of such soils (plant communities of Aphanion and Arnoseridion) prevail and weeds of basic soils are lacking, while in the Lake Constance region with basic soils and a rather warm and dry climate the latter, especially of the Caucalidion communities are much more frequent than crop weeds from acidic soils.

Early Neolithic land use

For the Neolithic, the situation is totally different. Written sources are lacking, and the evidence of land use is restricted to archaeological and botanical data. Therefore it is much more difficult to evaluate the land use systems. In her study of Neolithic farming in Central Europe, Bogaard (2004) has compiled the land use systems discussed for the Neolithic (Table 1). She also tried to falsify these models by applying modern statistical approaches to botanical onsite data. The Central European Neolithic is a period of more than three millennia, during which a lot changed, not only in culture, but also in economy and environment. Unfortunately Bogaard didn't differentiate the Neolithic in cultural or chronological phases.

Following the proposal of Lüning (1996), the Neolithic of Central Europe can be classified in five phases. During the first two phases, the Old and Middle Neolithic, settlement and agriculture was more or less restricted to the more or less dry loess belt with fertile soils. As a consequence, on-site data are restricted to charred plant remains, and good off-site evidence from lake or bog pollen profiles is almost lacking in Central Europe—an exception is the Luttersee (Beug 1992). In spite of this weak evidence, an agriculture with permanent fields, only summer crop cultivation, manual tillage, without manuring, and with animal grazing during fallow phases was postulated (Kreuz and Schäfer 2011; Kreuz 2010). These ideas, however, are mainly based on on-site macrofossil evidence.

As mentioned above, the only high-quality off-site data set from the Central European loess belt with clear evidence of Early Neolithic agriculture is Luttersee, central Germany (Beug 1992). The re-calculated diagram (Fig. 3) shows several Neolithic land use phases indicated amongst other things by considerable cereal pollen values. From these phases, only the oldest one corresponding to the late Linear Pottery culture and Middle Neolithic, shows a strong increase of non-arboreal pollen, stronger than in the Bronze Age and about as strong as in the pre-Roman iron Age. In contrast, the subsequent land use phases of the Neolithic show only slight and rather indistinct increases of NAP, but instead a clear increase of *Corylus,* but some of them have as much or even more cereals than the Linear Pottery/Middle Neolithic phase. This difference cannot be explained by the ecological differences between mixed oak forest and *Fagus sylvatica* woodland as in regions with early expansion of *F. sylvatica* like the pre-Alpine lowlands, because at Luttersee all Neolithic phases and even the Bronze Age coincide with the mixed oak forest phase. The expansion of *F. sylvatica* starts in the Bronze Age. These observations confirm the theses of Kreuz and Schäfer of permanent fields without fallow phases for the Old Neolithic, because by this method, also including manual tillage, the growth of grasses and some weeds such as Chenopodiaceae or *Polygonum aviculare* in the fields cannot be totally eliminated. On the other hand, *Plantago lanceolata* is extremely rare, and this is an argument against short fallow phases with animal grazing. In former times *P. lanceolata* was a crop weed, but indicating fields cultivated with short fallow phases and animal grazing rather than annually cultivated fields (Behre 1981; Willerding 1986).

The Young, Late and Final Neolithic land use systems

During the subsequent phases, Young, Late and Final Neolithic, the Pleistocene landscapes in northern central Europe and in the northern pre-Alpine lowlands were for the first time occupied by farmers. The circumstances and possible reasons for this expansion of the Neolithic lifestyle were for example discussed by Schier (2009). Here, the botanical evidence of land use is much better due to preservation of organic material in permanently wet soils.

An example which shows Young, Late and Final Neolithic land use in the northern pre-Alpine Lowlands, is the lower part of the pollen diagram from the centre of Mindelsee (Fig. 2). In contrast to Central Germany, the expansion of *F. sylvatica* at Lake Constance was much earlier and took place at about 5000 cal. B.C. During the land use phases of the fourth and early third millennium B.C., *Fagus* decreased. This decrease was compensated by an increase of *Corylus* and partly *Betula*, as in the Luttersee profile. Agriculture is indicated by cereal pollen, but an increase of NAP and especially of *P. lanceolata* is, as in the Luttersee profile, very weak. During these land use phases, charred particles are much more frequent than before and afterwards, not only in profiles from the shallow water zone of lake Constance itself with nearby lake shore settlements, but also in the profiles from the small lakes, from which no lake shore settlements are known. Then, after a phase with very low human impact and a strong increase of *Fagus* from the second half of the third to the beginning of the second millennium B.C., the "Extensive ard agriculture" starts at about 1800 cal. B.C. with a strong increase of NAP and *Quercus* and with high values of *P. lanceolata*. The events described are visible in all diagrams and indicate therefore a general trend for the region (Fig. 4).

This Late Neolithic land use system was tested experimentally in Schwäbisch Hall-Wackershofen from 1995 to 1997, and afterwards in Forchtenberg (Rösch et al. 2011). According to the results of these experiments, an agriculture with the use of fire and non-permanent fields, similar to modern tropical slash-and-burn agriculture and historical Reutberg- or Haubergwirtschaft (Wilmanns et al. 1979; Pott 1986), is the best if not the only method to practise successful agriculture with Neolithic tools and methods in a forested area on non-optimal soils (Ehrmann et al. 2014).

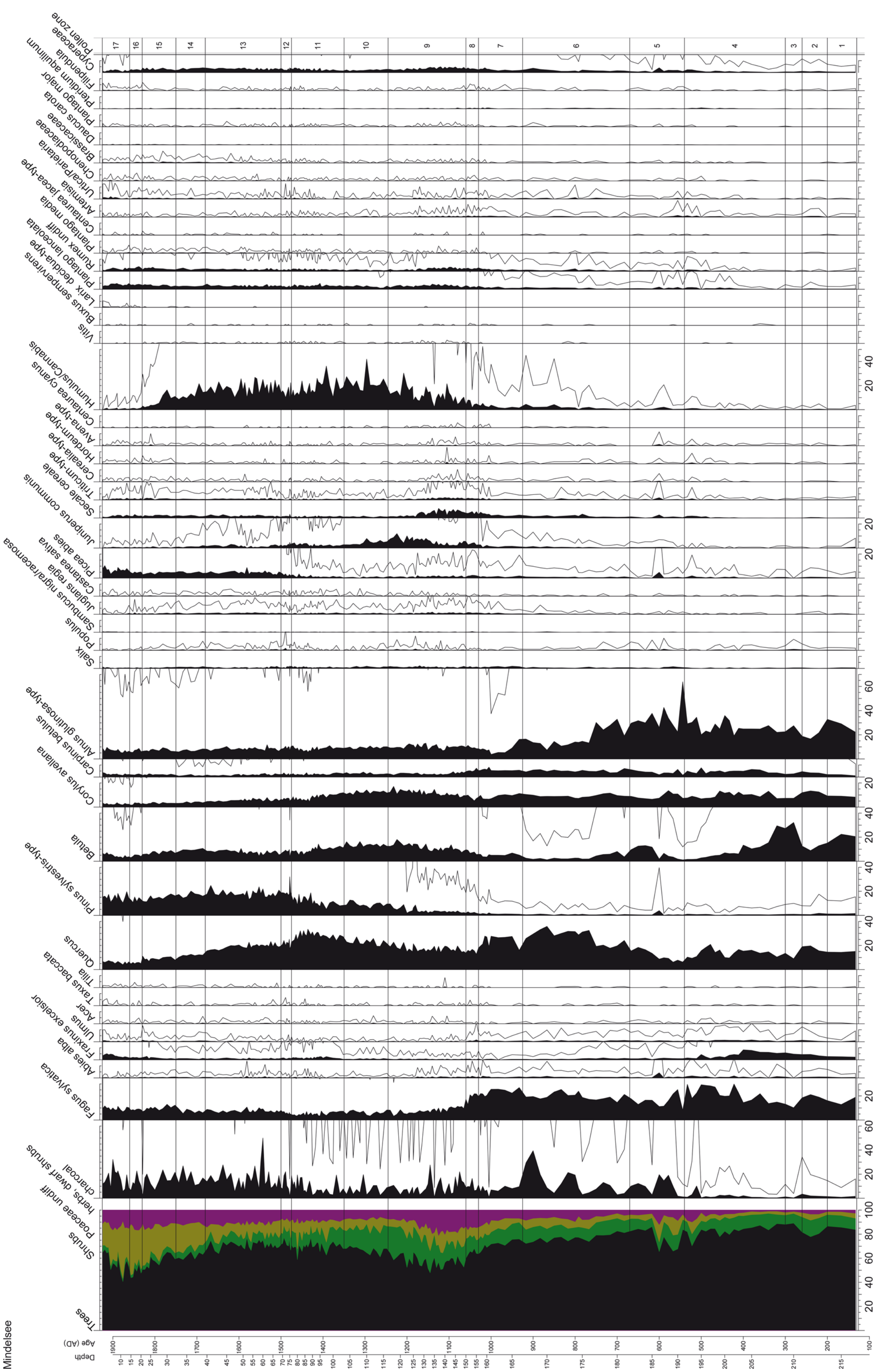


Fig. 2 Pollen diagram from Mindelsee calculated on base of total terrestrial pollen sum = 100 %; linear time axis cal. B.C./A.D.; *Alnus glutinosa*-type, Poaceae, and *Humulus/Cannabis* included in the pollen sum, Cyperaceae excluded; *Humulus/Cannabis* treated as a shrub; analyses: A. Kleinmann (prehistoric part), M. Rösch (historic part)

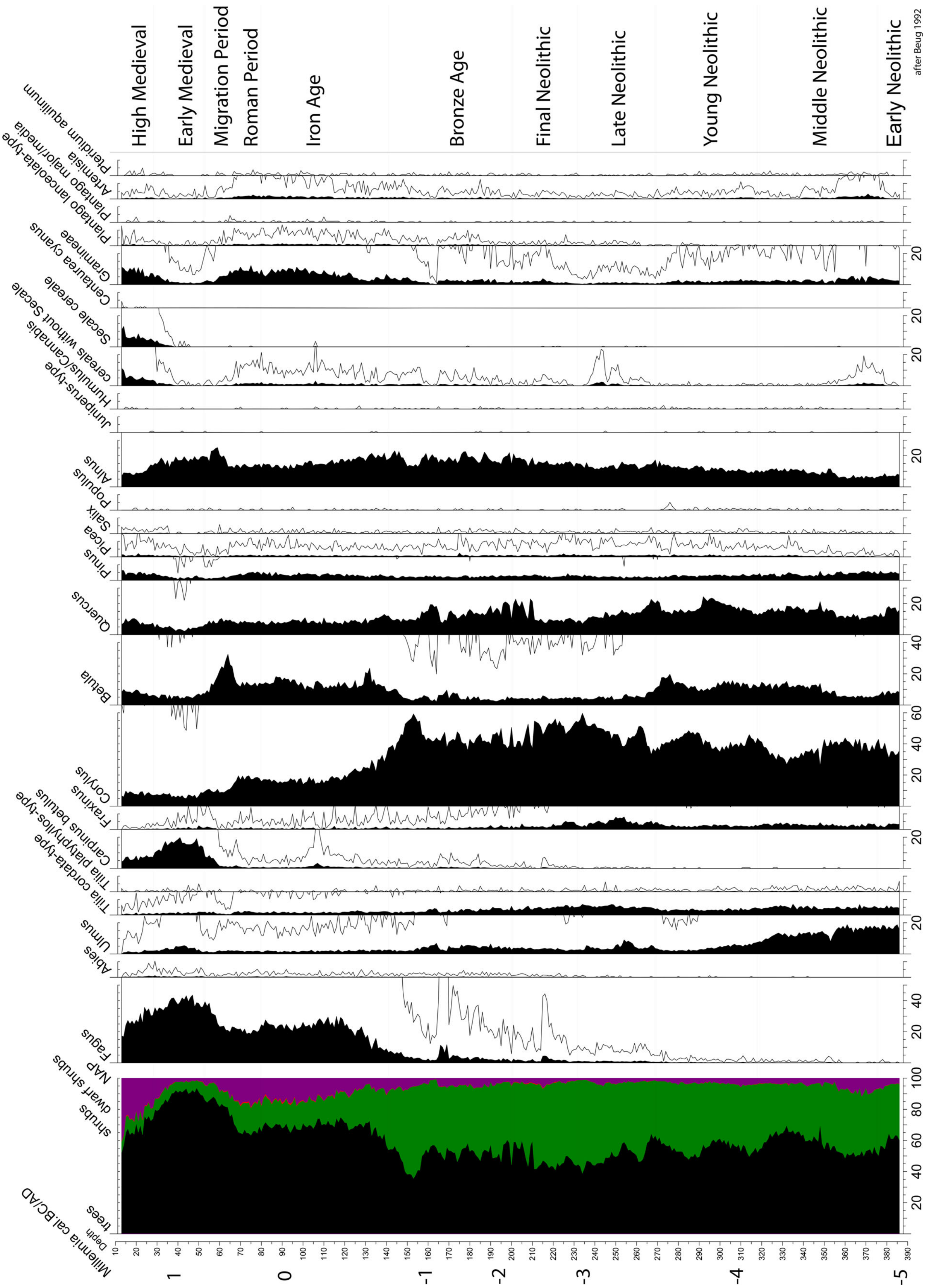


Fig. 3 Pollen diagram from Lutteranger near Göttingen, central Germany, after Beug (1992), modified, using EPD data; calculated on base of total terrestrial pollen sum = 100 %; linear depth axis; time scale (millennia cal. B.C./A.D.) and archaeological periods according to Beug (1992)

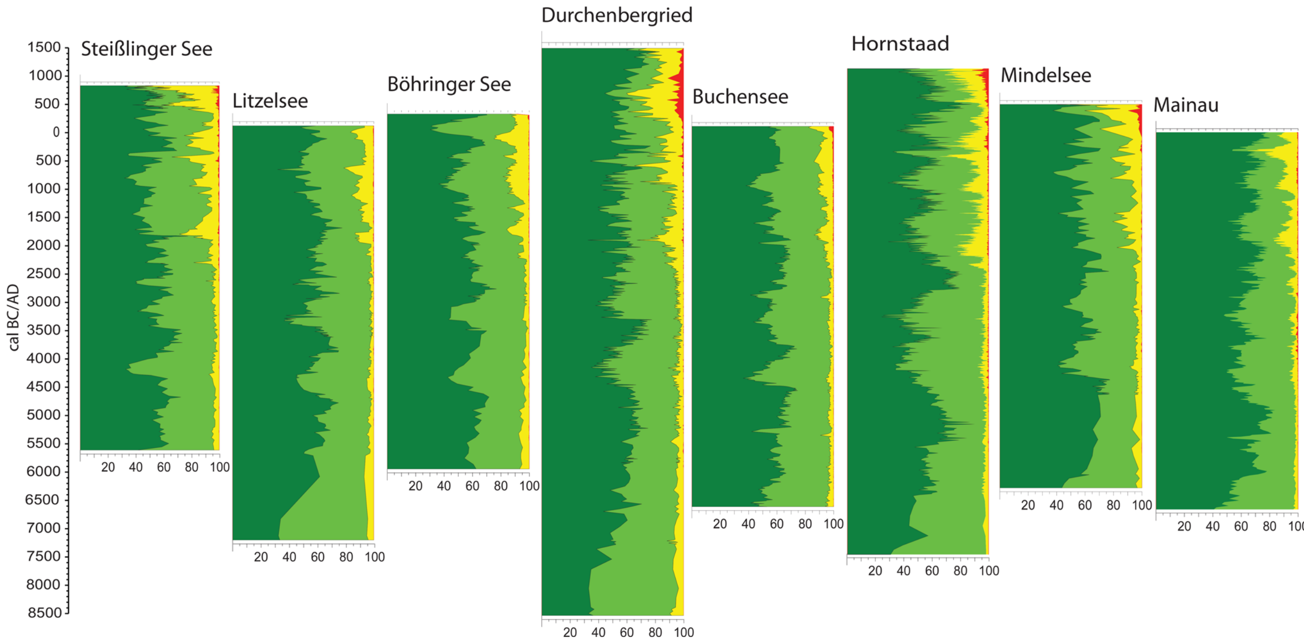


Fig. 4 Pollen diagrams from the Lake Constance region, a summary showing only main diagrams. Time axis years cal. B.P.; percentages based on total land pollen sum; *dark green* trees, *light green* shrubs, *yellow* NAP including Poaceae indet, *red* cereal sum

On-site plant macrofossil evidence

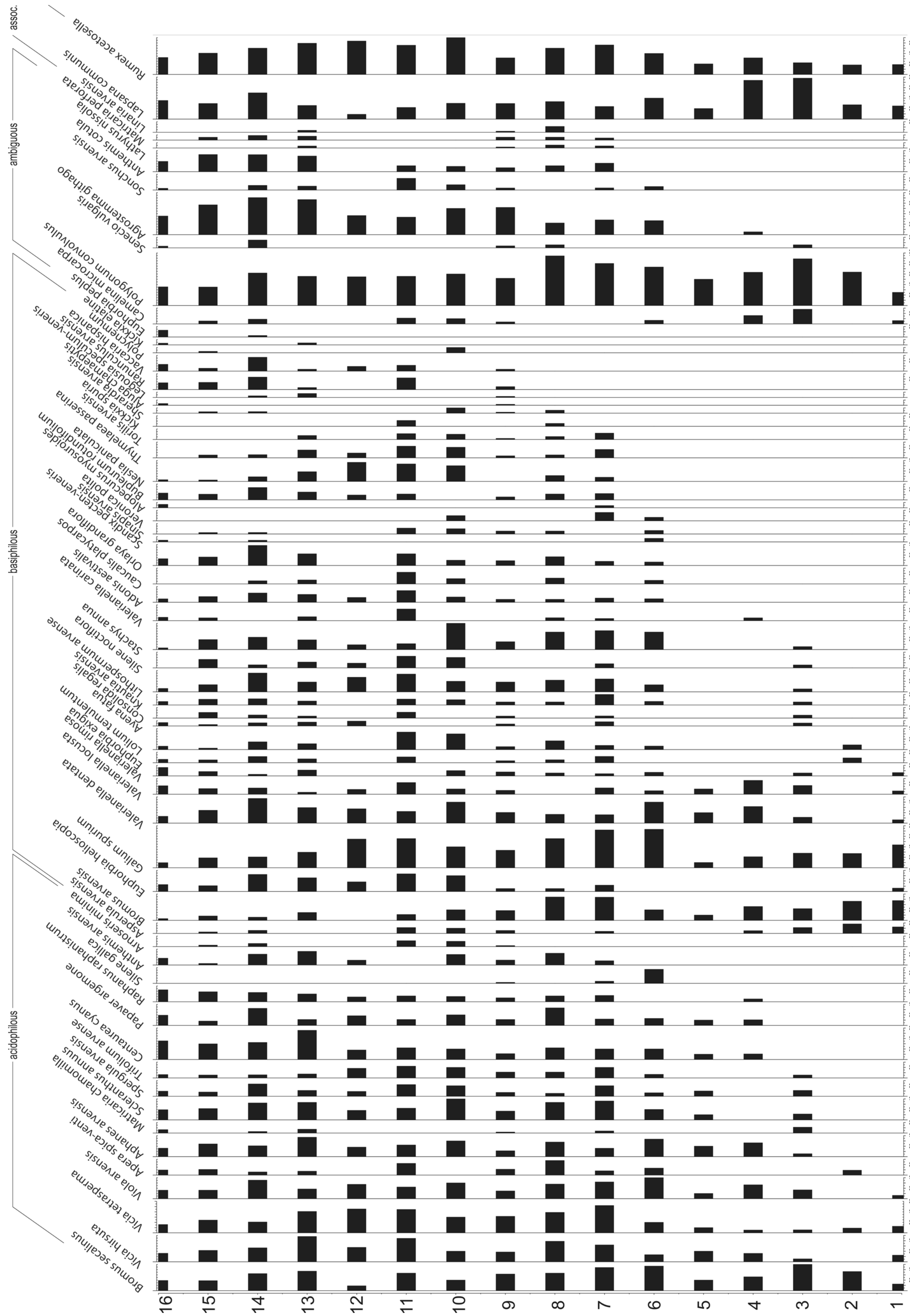
"Extensive ard agriculture"

Based on macrofossil evidence, the "Extensive ard agriculture" is characterized by a large variety of cereals and other crops, however often dominated by a "main stream" cereal like *Hordeum vulgare* (hulled barley) and *Triticum spelta* in the pre-Roman Iron Age, the latter during the Roman period, and *Secale cereale* as well as *Avena sativa* in the High Medieval period (Rösch et al. 1993; Fischer et al. 2010; Rösch 2009; Arnold and Rösch 2011; Fig. 5). These "main stream" cereals enable good yields even on less fertile soils. Especially the High Medieval main crops can tolerate rather acidic soils. The "Medieval" fields were strongly infested by winter crop weeds such as *Agrostemma githago* or *Centaurea cyanus* (Fig. 5). Crop weeds from dry, basic soils, of the so-called Caucalidion communities, such as *Adonis aestivalis*, *Caucalis platycarpos*, *Orlya grandiflora*, *Bupleurum rotundifolium*, *Neslia paniculata*, *Thymelaea passerina* and *Vaccaria hispanica* were rather common, as well as crop weeds from acidic soils like *Scleranthus annuus*, *Centaurea cyanus*, *Papaver argemone*, *Aphanes arvensis* or *Arnoseris minima*. But the plant communities did not only consist of these species and species from root crops or gardens such as *Chenopodium album* and others, but also contained perennials like *P. lanceolata* and different grasses, which are today typical of meadows and pastures (Karg 1996).

The Old Neolithic

Back in the Linear Pottery culture, the agriculture is focused largely on only two cereal taxa, *Triticum monococcum* and *T. dicoccon*, two legumes, *Pisum sativum* and *Lens culinaris*, and two oil and fibre plant taxa, *Linum usitatissimum* and *Papaver somniferum* (Kreuz and Schäfer 2011). This small and reduced assemblage of cultivated plants, compared with the earlier situation in the Near East and southeastern Europe, can be interpreted in different ways. In any case we can suppose that it was large enough for people to survive and therefore reflected favourable ecological conditions for arable farming. Among the winter crop weeds only *Bromus arvensis*, *B. secalinus*, *Galium spurium* and *Polygonum convolvulus* were common (Kreuz 2010). All others, *Asperula arvensis*, *Papaver dubium/rhoeas*, *Scleranthus annuus*, *Valerianella dentata*, *V. locusta*, *Vicia hirstua* and *V. tetrasperma,* occur only sporadically. The common weeds indicate rather fertile, loamy soils and were perhaps partly used as gathered food.

Looking at so far the best investigated site of the Linear Pottery culture, Vaihingen/Enz (Bogaard 2011), and focusing on crops and weeds with the omission of cereal chaff and *Chenopodium album*, cereal grains are most numerous, but wild plants are rather common (Fig. 6). Including *Ch. album* with its more than 10,000 items would have made wild plants much more common than crops. We must assume that *Ch. album* at Vaihingen was either collected or even grown, as Bogaard (2011) suggests, or grew


assoc.
ambiguous
basiphilous
acidophilous
Rumex acetosella
Lapsana communis
Linaria arvensis
Matricaria perforata
Lathyrus nissolia
Anthemis cotula
Sonchus arvensis
Agrostemma githago
Senecio vulgaris
Polygonum convolvulus
Camelina microcarpa
Euphorbia peplus
Kickxia elatine
Vaccaria hispanica
Ranunculus arvensis
Legousia speculum-veneris
Ajuga chamaepitys
Sherardia arvensis
Kickxia spuria
Torilis arvensis
Thymelaea passerina
Neslia paniculata
Bupleurum rotundifolium
Alopecurus myosuroides
Veronica polita
Sinapis arvensis
Scandix pecten-veneris
Orlaya grandiflora
Caucalis platycarpos
Adonis aestivalis
Valerianella carinata
Stachys annua
Silene noctiflora
Lithospermum arvense
Knautia arvensis
Consolida regalis
Avena fatua
Lolium temulentum
Euphorbia exigua
Valerianella rimosa
Valerianella locusta
Valerianella dentata
Galium spurium
Euphorbia helioscopia
Bromus arvensis
Asperula arvensis
Arnoseris minima
Anthemis arvensis
Silene gallica
Raphanus raphanistrum
Papaver argemone
Centaurea cyanus
Trifolium arvense
Spergula arvensis
Scleranthus annuus
Matricaria chamomilla
Aphanes arvensis
Apera spica-venti
Viola arvensis
Vicia tetrasperma
Vicia hirsuta
Bromus secalinus
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1

◀**Fig. 5** Constancy of important crop weeds for historical periods from the Old Neolithic to Modern Times in South-West Germany, referred to sites; percentages, based on site numbers per period; 1 Early Neolithic, 2 Middle Neolithic, 3 Younger Neolithic, 4 Late Neolithic, 5 Final Neolithic, 6 Early/Middle Bronze Age, 7 Late Bronze Age, 8 Hallstatt and early Latène period, 9 middle and late Latène period, 10 Roman period, 11 Migration period, 12 Early Medieval (Merovingian period), 13 Early Medieval (Carolingian and Ottonian period), 14 High Medieval, 15 Late Medieval, 16 Modern times

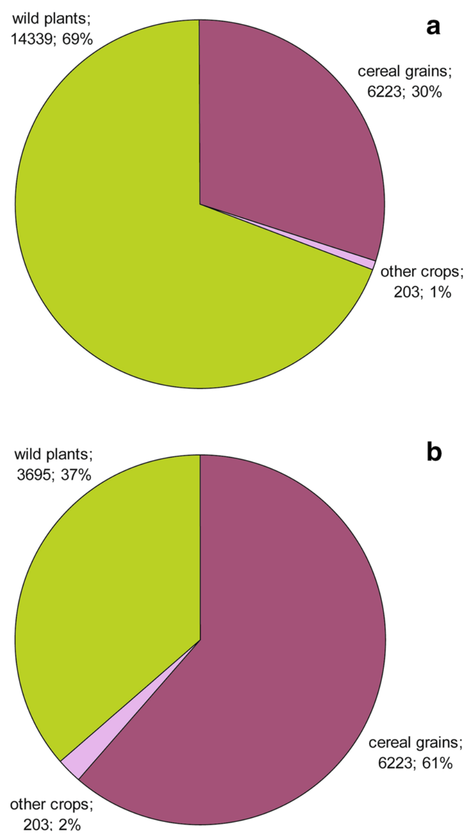

Fig. 6 Charred plant remains of the Linear Pottery site of Vaihingen/Enz, South-west Germany, after Bogaard (2011), percentages of cereals, other crops, and wild plants, based on the total sum of plant remains **a** *Chenopodium album* included, **b** *Ch. album* excluded

locally in the settlement itself. A classification of the wild plants of Vaihingen (excluding *Ch. album*) reveals winter crop weeds as the most common group (Fig. 7). Root crop weeds, plants from grassland or fallow land, and ruderals are rather abundant. The winter crop weeds are the well-known species described already by Knörzer (1971). The data confirm generally the ideas of Kreuz and Schäfer (2011) of permanent fields, but their idea of only summer crop cultivation is not supported by the data presented here.

Young, Late and Final Neolithic

Looking at the later phases of the Neolithic, the huge data set of Hornstaad (Maier 2001) is most significant. The

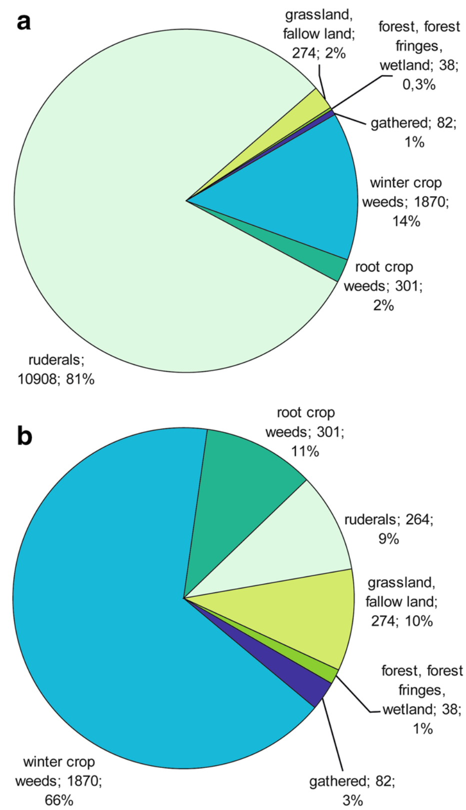

Fig. 7 Wild plants of the Linear Pottery site of Vaihingen/Enz, South-west Germany, after Bogaard (2011), classified in ecological groups; percentages, based on the total wild plant sum **a** *Chenopodium album* included, **b** *Ch. album* excluded

agriculture was based on four cereals, *Triticum monococcum*, *T. dicoccon*, *Hordeum vulgare* and *T. durum*, of which the latter was most common. *Linum usitatissimum* and *Papaver somniferum* were rather common, but *Pisum sativum*, the only pulse, was rare. From the charred stocks of several houses, burned down in 3909 B.C. (Billamboz 2006; Matuschik 2011) more than 25,000 cereal grains were identified. The stocks consisted of about 95 % cereal grains, mostly of *T. durum/turgidum* (Fig. 8). *T. durum* especially is a rather demanding crop as regards soils as well as climate (Brouwer 1972; Lieberei et al. 2007). Other crops and collected useful plants together represented about 4 % and weeds about 1 %. The stocks were unprocessed and therefore most probably cleaned of weeds. Even assuming ear harvest, the small proportion of weeds is striking and resembles the purity of the harvest from the Forchtenberg slash-and-burn fields (Ehrmann et al. 2014). A considerable amount of them are perennials. Among the annual weeds, only *Polygonum convolvulus*, *Valerianalla dentata*, *Vicia hirsuta* and perhaps *Veronica* cf. *arvensis* can be considered as typical crop weeds. The others are ruderals, root crop weeds, or plants of woodland fringes or clearings. Based only on weed species composition, the

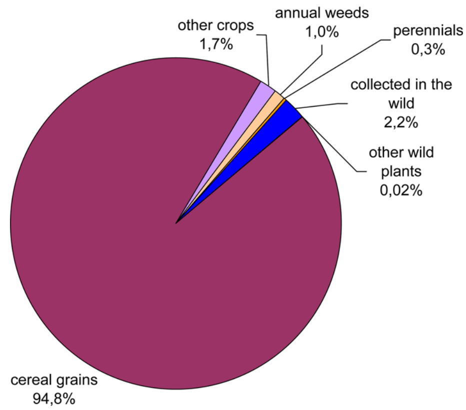

Fig. 8 Botanical composition of charred stocks of burned houses at Hornstaad, Lake Constance, after Maier (2001); percentages based on the total sum of plant remains, cereal chaff disregarded

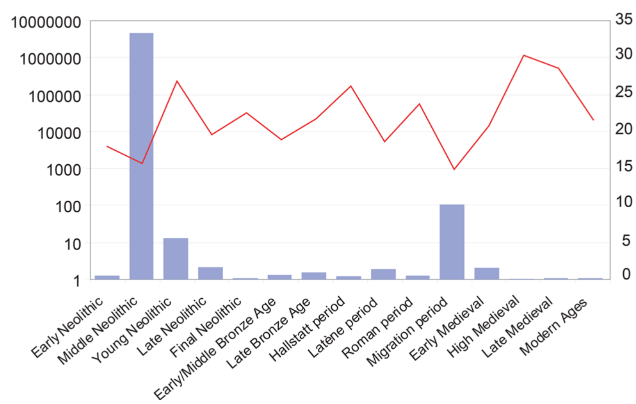

Fig. 9 Cereal remains (all types of remains) from archaeological sites in South-west Germany summed up for historical periods. Absolute counts, logarithmic scale on the left, red line. Percentages of free-threshing wheat (*Triticum aestivum/durum*, all types of remains) based on the sum of cereal macrofossils for historical periods in South-west Germany, *right hand scale*, *blue columns*

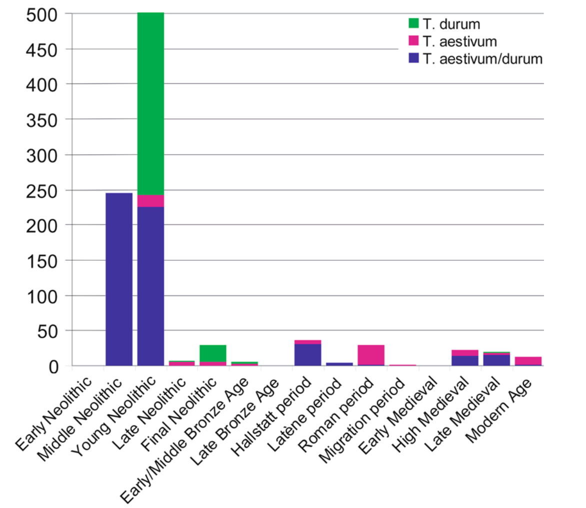

Fig. 10 Tetraploid, hexaploid and undifferentiated forms among the free-threshing wheat chaff classified for historical periods in South-west Germany (counted numbers)

differences between Hornstaad and the weed spectra of the Linear Pottery culture are small, compared with the differences between the Neolithic and later phases. On the other hand, the weed percentages of Hornstaad are much lower than those of Vaihingen, and *Bromus* species as well as perennial grasses are much more infrequent.

So far we can conclude, the land use systems of the later stages of the Young and Late Neolithic were totally different from the land use of the Early Neolithic as well as from the "Extensive ard" land use system of the Bronze Age onwards. This is clearly visible not only by looking at the best investigated sites, but is supported by the results from many other, less well investigated sites.

This difference of the Young Neolithic from the phases before and after is also indicated by the particular cereal spectra of this phase (Figs. 9, 10). This evaluation is based on data from 16 Old Neolithic, 11 Middle Neolithic, 42 Young Neolithic and 19 Late/Final Neolithic sites in Southwest Germany. Together with the later periods, in total 368 archaeological sites were evaluated.

The highest percentages of *T. aestivum/durum* occur in the Middle Neolithic and in the Migration period, but these periods have 11 and 10 sites respectively and too few features with too few plant remains investigated to draw further conclusions. Therefore the high percentages of *T. aestivum/durum* should not be over-interpreted (Table 3). The very high percentage of *T. aestivum/durum* for the middle Neolithic is based on 219 grains, most from a single small stock from a Bischheim site at Creglingen (Rösch 2013).

With the exception of the High and Late Medieval, the Young Neolithic has the most cereal remains, and also, with more than 5 %, a considerable percentage of *T. aestivum/durum* grains. In all other periods with the exception of the two first mentioned, the percentages are below 2 %. Well preserved chaff can be differentiated further (Maier 1996). In this case, only Young and Final Neolithic sites provided considerable numbers of tetraploid naked wheat (Fig. 10).

Conclusions

The on-site evidence is mainly based on lake-shore sites with their special preservation conditions. Whether these results can be transferred to the contemporaneous cultures of the loess belt, for example the Michelsberg culture where the archaeobotanical data are very poor, needs to be tested by further investigations, taking in account the different preservation states. However, pedological and

Table 3 Cereal grains, other crops and weeds from charred stocks (chaff not included) of burned houses at Hornstaad IA, Lake Constance, after Maier (2001)

House no.		10	11	12	1	3	9	11	12	1	12	1/11	Sum
Cereal grains													
Triticum durum-type	caryopse	8,466	1,045	2,568	2,317	863	1,097	160	40	102	837	17	17,512
T. monococcum/dicoccon	caryopse	253	117	177	111	12	297	77	74	300	2,068	82	3,568
Hordeum vulgare	caryopse	382	93	147	230	58	2,652	357	334	28	432	33	4,746
Other cultivated plants													
Linum usitatissimum	capsule segm.		2	6	12						2	2	24
Linum usitatissimum	capsule/seed	2/6	1/18	1/12	2/18		1/9	3/2	2/12		13/46	/5	25/128
Papaver somniferum	seed	125			68	2	72			2	5		274
Anethum graveolens	mericarp				4					1			5
Collected in the wild													
Brassica campestris	seed	79	1	4	15	2		4	2	5	21	6	139
Descurainia sophia	seed	444		1	1					2			448
Crop weeds													
Arenaria serpyllifolia	seed	1								2			3
Bromus cf. *sterilis*	caryopse	1											1
Capsella bursa-pastoris	silicula/seed	1/5			1						3		5/5
Chenopodium album	seed	2		4	2					1			9
Ch. hybridum	seed	3											3
Ch. polyspermum	seed	11		5	2				1				19
Galeopsis tetrahit-type	achene	77	13	2	28			1	1		17	2	141
Galium aparine	seed			2									2
Lapsana communis	achene	6	11	2	3	7				2			31
Myosoton aquaticum	seed									4			4
Polygonum convolvulus	fruit	9	2	1	2	2		2		1	10		29
P. minus	fruit									1			1
P. persicaria	fruit			1									1
Stellaria media	seed			2									2
Valerianella dentata	fruit	14											14
Veronica cf. *arvensis*	seed				1								1
Vicia angustifolia	seed										1		1
V. hirsuta	seed	2		1	1	1				1			6
No crop weeds from actualistic point of view													
Aquilegia vulgaris	seed				1								1
Carex hirta	fruit				1								1
Malva sylvestris	fruit										49		49
Moehringia trinerva	seed	6			1						1		8
Nepeta cataria	achene					1							1
P. dumetorum	fruit	2											2
Ranunculus repens	nutlet	1		1									2
Silene vulgaris	seed	5	2		5	1						1	14
Verbena officinalis	achene			1									1
Fruits collected in the wild													
Corylus avellana	nut				8						1		9
Malus sylvestris	seed	1											1
Physalis alkekengi	seed											1	1
Rubus idaeus	pit	1									1		2
Sambucus nigra	seed	1											1
Woodland, shrubs, shore													
Betula sect. *Alba*	nutlet								1				1
B. pendula	fruit scale											2	2
Carex cf. *riparia*	fruit										1		1
Cladium mariscus	nutlet				2								2

geochemical results from the Rhineland emphasise the extent and importance of fire use in the Young Neolithic agriculture even in the loess belt as well as questioning the natural origin of the Black Earth in the Rhineland (Eckmeier et al. 2007, 2008).

If we assume that the choice of crops is not only a cultural question, but an expression of the ecological conditions in agriculture to which different crops react differently, and when we further assume that these ecological conditions in agriculture are only partly dependent on natural factors like climate and soils, but to a high degree on the agricultural system, we can deduce that the crops are proxies for the agricultural system as well as weeds and other wild plants.

The presented comparison underlines the special status of the Young Neolithic in the agricultural history of southern central Europe. As a well-fitting explanation for the observations mentioned above, a shifting cultivation with slash-and-burn for the Young Neolithic phase at Lake Constance has been suggested (Rösch 1987). The arguments are:

- No permanent open vegetation as in earlier and later periods, deduced from pollen diagrams
- Expanded coppiced forests and shrubs and regular burning in the woodland, deduced from pollen diagrams
- Scarceness of real crop weeds, deduced from the pollen and macrofossil record
- High frequency of *T. durum/turgidum*, deduced from on-site plant macrofossils.

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