Wild West Frisia : the role of domestic and wild resource exploitation in Bronze Age subsistence

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6. Crop husbandry

6.1 INTRODUCTION

Crop husbandry in West Frisia is assumed to have been practiced in a small-scale mixed subsistence farming context. The role of crop husbandry in this type of subsistence as well as the practices related to it are researched in this chapter in a similar manner to the previous two chapters: by re-evaluating the old and new available data on the subject. Previous research and the current view towards crop husbandry in Bronze Age West Frisia is represented first, together with its main components. These main components are challenged in this chapter by comparing them with the results of the new analyses performed on the West Frisian data. Further explanation of how these main components are challenged is provided in the methods section (section 6.2).

6.1.1 Previous research

Crop husbandry refers to all activities which are performed regarding planting and harvesting crops, as well as the processing and storing of the harvest. Clearly, many activities are required to ensure that a crop is performing well in the field, so that farmers can obtain a good crop yield in terms of quantity and quality. West Frisian crop husbandry has previously been researched by Buurman (1996), who based her model mainly on the analysis of botanical macro remains from several excavated Bronze Age sites. The charred remains of crops and crop weeds provided valuable information on both the range of crops available in the Bronze Age, as well as the specific crop husbandry practices performed in West Frisia. For example, based on charred wild plant remains of waterside vegetation and charred concentrations of crop remains, Buurman concluded that arable fields in West Frisia were very wet, and only contained one crop species at a time (1) (Buurman 1996: 28, 190). The crops available to West Frisian farmers were mainly emmer wheat and barley, of which the hulled variety was cultivated during most of the Bronze Age (2). In the Middle Bronze Age, emmer wheat and hulled barley were of equal importance (2a) (Buurman 1996, 18), whereas in the Late Bronze Age, hulled barley was the only cultivated crop (2b) (Buurman 1996, 19). Sowing seasonality was reconstructed by Buurman based on the remains of crop weeds: in West Frisia, crops were sown in spring, and can thus be characterised as summer crops (3) (Buurman 1996, 190). Fertilisation of arable fields was achieved by applying a combination of animal dung and household waste (4), evidenced by the remains of small bones and ceramics found in plough layers (Buurman 1996: 25, 190). Harvesting of crops occurred by reaping low on the stalk with a bronze sickle, or, in the Late Bronze Age, by uprooting crops (5) (Buurman 1996: 25, 191). After harvest, the crops were processed in and around the house, and were finally stored as sheaves outside the house until further processing for consumption was necessary (6) (Buurman 1996, 191).

The role of crop husbandry for Bronze Age subsistence in West Frisia was only inexplicitly stated by Buurman by closely linking her results to the animal husbandry results of IJzereef. Buurman postulates that in the Middle Bronze Age, crop husbandry formed the main subsistence strategy together with animal husbandry for meat and traction; in the Late Bronze Age, domestic animals were mainly used for milk production, rather than for pulling the plough (Buurman 1996, 26, Table 4). In combination with the incorporation of the old landscape model and inherent calculations on available land for crop husbandry, Buurman concludes that in the Late Bronze Age, crop husbandry could not be practiced to the extent where people could entirely sustain themselves (7) (Buurman 1996, 31-2).

Clearly, most of Buurman's research towards crop husbandry practices was performed with the previous landscape model for West Frisia in mind. Since this landscape model is inconsistent with new data and analysis (cf. Chapter 2), it is interesting to re-evaluate the old and new botanical data in combination with

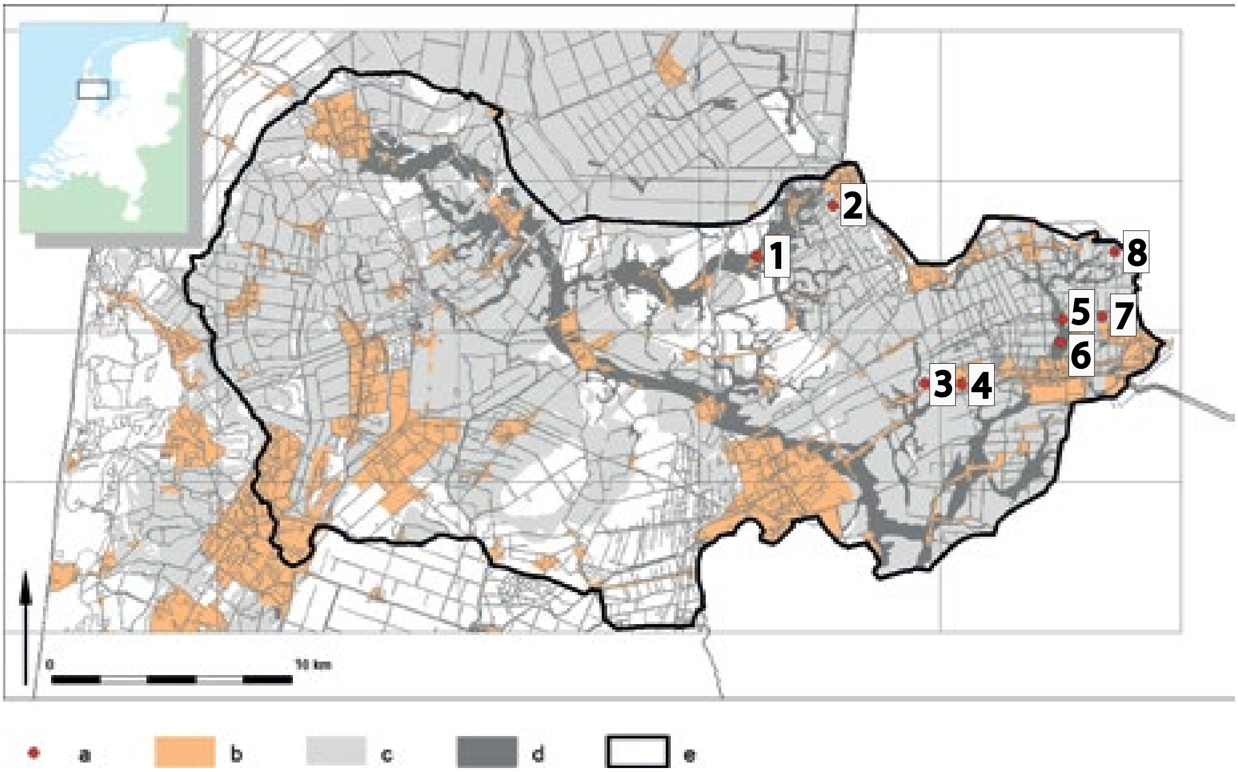

Figure 6.1. Overview of the sites of West-Frisia that yielded (large amounts of) crop remains. 1: Twisk; 2: Medemblik Schepenwijk II; 3: Westwoud; 4: Hoogkarspel Tolhuis and Hoogkarspel Watertoren; 5: Bovenkarspel Het Valkje; 6: Bovenkarspel Het Monument; 7: Enkhuizen Kadijken; 8: Enkhuizen Rikkert; a: location of an excavated site; b: present-day urban areas; c: tidal marsh deposits; d: creek deposits; e: outline of present-day West Frisia.

the new landscape model in order to identify possible differences in conclusions about the role and praxis of crop husbandry in West Frisia.

6.1.2 The proxies and the sites

The proxies used for the re-evaluation and re-analysis of the old and new data on crop husbandry include ethnography, ethnobotany, biology, ecology, archaeobotany, and archaeology (section 6.2). The combination of these different disciplines provided a clear basis for the creation of what basic principles can be expected for small-scale crop husbandry (section 6.3), and the subsequent analysis of these aspects (section 6.4).

Although charred remains of crops and wild plants were uncovered at most of the excavations performed in West Frisia, only some sites possessed large enough quantities of charred botanical remains to allow for a more detailed analysis. Therefore, only two old and two new excavated sites are employed for the re-evaluation of the role and praxis of crop husbandry. Information on these sites is summarized in Figure 6.1 and Table 6.1.

Throughout the text, site names are addressed by their first name only, unless further specification is necessary to avoid confusion between different sites from the same location.

6.1.3 Main current model components

The main components of the current view of crop husbandry, which are challenged in this chapter, are as follows:

(1) Arable fields in West Frisia were sometimes wet and contained only one crop species at a time.
(2) West Frisian crops were mainly emmer wheat

and hulled barley for most of the Bronze Age.
(2a) In the Middle Bronze Age, emmer wheat and hulled barley were of equal importance.
(2b) In the Late Bronze Age, solely hulled barley was cultivated.
(3) Sowing of crops occurred in spring.
(4) Fertilising fields was achieved by applying a combination of household waste and animal dung.
(5) Harvesting ripe crops was performed by reaping low on the stalk with a bronze sickle, and in the Late Bronze Age, by uprooting crops.
(6) Processing of the harvest occurred in and around the house and harvest was stored in sheaves.
(7) In the Late Bronze Age, people were not able to practice crop husbandry to the extent required to complete subsistence.

6.2 METHODS

The different methods applied to investigate the role of crop husbandry in Bronze Age West Frisia are shortly presented here. Similar to the previous two chapters, the main approach in this chapter is to identify multiple activities related to crop husbandry (Table 6.2) and create an expectation of what each component entails (section 6.3). Note that no separate basic aspect of "use" is included in Table 6.2, because it is assumed that crops were primarily grown for human consumption. Other uses for crops and their residues are discussed in section 6.4.8.4.

The individual components outlined in Table 6.2 are first analysed separately in order to create an understanding of every part in the West Frisian subsistence economy (section 6.4). After the analysis of the separate basic principles of crop husbandry, they are re-combined and integrated to view crop husbandry entirely. During this analysis, the available botanical data is used, and the data is also compared to the expectation made in section 6.3. This comparison provides indications for what components should be a part of small-scale crop husbandry practices, but are missing from the West

Table 6.1. Information on the sites of West-Frisia used for the analysis of crop husbandry.

Site location	Typonym	Excavated	Date	Dating method	Sieving mesh size	Reference(s)
Bovenkarspel	Het Monument	1977	1500-800 BC	pottery typology	n/a	Roessingh in prep.
Bovenkarspel	Het Valkje	1974-1978	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Buurman 1996, 83-104
Enkhuizen	Kadijken	2007-2009	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Moolhuizen & Bos 2011, 259-69
Enkhuizen	Rikkert	2012-2015	1500-800 BC	pottery typology	n/a	unpublished
Hoogkarspel	Tolhuis	1964-1969	1500-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	van Zeist 1968-1970
Hoogkarspel	Watertoren	1973-1978	1500-800 cal BC	14C-dating	0.25-1.0 mm	Pals 1977, 189-225
Twisk		1980	1300-1100 BC	14C-dating	0.25-1.0 mm	Buurman 1996, 37-68
Westwoud	1988	1988	1400-800 cal BC	AMS-dating	0.25-1.0 mm	Buurman 1996, 107-56
Medemblik	Schepenwijk II	2007	1450-800 cal BC	14C-dating and pottery typology	0.25-1.0 mm	Kooistra 2010, 125-42

Table 6.2. Basic aspects related to crop husbandry.

Crop husbandry	Related to:
a. Arable field size and crop composition	land and crops belonging to the household
b. Soil preparation	tending to arable fields
c. Cultivation	tending to crops
d. Handling and related locations	post-harvest processing and storage
e. Arable field soil conditions and locations	location and improvement of arable fields
f. Seasonality	seasonal activities related to crops

Frisian archaeobotanical assemblage. The absence of such components is further explored in section 6.4.8 where the effects of archaeological methodology and taphonomical processes on the data are assessed. By using multiple proxies and recent research in the analysis of the West Frisia data more detailed information on the praxis of crop husbandry, as well as it social organisation was obtained, which would not have been possible based on the use of only one discipline.

6.2.1 Ethnography

The ethnographic study of Murdock (1981) was used to assess the general role of crop husbandry within small-scale mixed farming communities, similar to the previous chapters 4 and 5, and with the same selections applied as in these Chapters (Appendix A1.4). More detailed ethnographic parallels were chosen for specific aspects related to crop husbandry, including soil preparation, cultivation, and post-harvest practices. Each of these parallels are elaborated upon in the respective sections.

The employed research of Murdock for the general importance of crop husbandry contained examples from different areas of the world, which allowed for the understanding of consistent crop husbandry characteristics regardless of geography, time period or climate. The more detailed examples were chosen to most closely reflect the presumed environmental conditions of Bronze Age West Frisia.

6.2.2 Ethnobotany

An in-depth ethno-botanical study of Romanian and Slovakian small-scale subsistence farming (Hajnalová & Dreslerová 2010) was employed to investigate specific crop husbandry practices.

This parallel was chosen because it is the only example of an ethnobotanical study that incorporates both qualitative as well as quantitative data on all the basic aspects of crop husbandry in a small-scale mixed farming situation. Furthermore, this is the only study of this scope known to the author that researches such a farming situation in a region outside southern Europe (see below). The researched communities still cultivated einkorn and emmer, two of the main cereals from late prehistory, in a traditional manner, without the use of heavy machinery. Even though most farms were located in central Europe in the Carpathian mountains, it is assumed that the practices reflect north-western European land use in a more accurate manner than many of the ethnobotanical studies undertaken in the Mediterranean. Of course, several aspects of crop husbandry in a hilly, central European environment will be different from low-land crop cultivation, and these differences are discussed where appropriate.

6.2.3 Ecology

Ecological information regarding the growth requirements of crop weeds (Ellenberg *et al.* 1991) was employed to research soil characteristics of arable fields.

6.2.4 Biology

The biological information on crop weeds was employed to investigate crop husbandry practices such as sowing time, harvesting height, and fallow periods. For references regarding these crop husbandry practice reconstructions, see sections 6.4.2 and 6.4.3.

6.2.5 Archaeobotany

Archaeological information for this research mainly consisted of an overview of crops available in the Bronze Age in general (Stika & Heiss 2013), in order to assess the potential range of crops present during that time. Differences and similarities in the crop composition between West Frisia and other areas north-western Europe thus became apparent, which allowed for further interpretation of possible crop choices made by Bronze Age farmers in West Frisia.

6.2.6 Archaeology

Archaeology was employed to investigate the different field systems present in the Bronze Age, as well as the range of possible storage locations available at this time.

6.3 CREATING AN EXPECTATION OF CROP HUSBANDRY PRACTICES

The relative role of crop husbandry in small-scale mixed farming communities was first investigated, similar to the previous chapters, by selecting specific cultural parallels from the ethnographical work by Murdock (1981). The analysis has resulted in an average contribution of crop husbandry to subsistence of 59% (Appendix A1.4), although the precise meaning of this value remains unclear based on the statements of Murdock (cf. Chapter 4, section 4.3). However, crop husbandry can be regarded as the main contributor to subsistence by being a source of staple food for farmers, through providing more than half of the required means for subsistence. Furthermore, in every selected mixed farming culture, crop husbandry always aids subsistence more than animal husbandry, regardless of the size of the community.

The manner in which crop husbandry is practiced in small-scale communities was also researched, starting with the size of arable fields. In general, the size of arable land is dependent on several restrictions. First of all, the available land for crop husbandry can be a deciding factor in how large a (set of) field(s) can become. Furthermore, the type of farming system, and its inherent labour force size can be a restriction in the sense of available time and people. Lastly, climate, soil properties, and plant species characteristics decide the yield of a crop at a certain location and therefore the amount of land required.

For small-scale mixed subsistence farms, the size of the arable land is often restricted most by the number of people available for labour: even though the climatic conditions might be favourable and ample arable land might be available, it is often not feasible to cultivate larger field sizes with the given amount of time and size of labour force for sowing and harvest of the crops. The restrictions of arable land size are closely linked to the adopted land use strategy of farmers, which can be intensive, extensive, or a combination of both.

In the Encyclopaedia Brittanica, intensive agriculture [9]is classified as a “system of cultivation using large amounts of labour and capital relative to land area. Large amounts of labour and capital are necessary for the application of fertilizer (...) to growing crops” and “a farm using intensive agriculture will require less land than an extensive agriculture farm to produce a similar profit”.

Extensive agriculture is, logically, defined as a “system of crop cultivation using small amounts of labour and capital in relation to area of land being farmed. The crop yield in extensive agriculture depends primarily on the natural fertility of the soil, terrain, climate, and the availability of water.”

In practice however, small-scale farmers often adopt a mixture of intensive and extensive farming.

In archaeology, the model of Boserup (1965) is frequently used for the interpretation of crop husbandry. She developed a system of classification to show the dynamic properties of crop husbandry, in which she discerned five main land use types. The types are: forest fallow, bush fallow, short fallow, annual cultivation, and multiple cropping; the latter

9. Although agriculture is applied here to the cultivation of crops, its definition usually includes the practice of cultivating the soil, producing crops, and raising livestock. Therefore, the more specific term crop husbandry is used for the rest of the chapter.

Table 6.3. Comparison of farming operations in different farming systems (adapted from: Pingali *et al.* 1987).

	Farming System				
Operation or situation	**Forest fallow**	**Bush fallow**	**Short fallow**	**Annual cultivation**	**Multiple cropping**
Land clearing	Fire	Fire	None	None	None
Land preparation and planting	No land preparation; use of digging stick to plant roots and sow seeds	Use of hoe and digging stick to loosen the soil	Plough	Animal-drawn plough and tractor	Animal-drawn plough and tractor
Fertilization	Ash; perhaps household refuse for garden plots	Ash; household waste for garden plots	Animal dung or other manure; sometimes composting	Manure; sometimes human waste; composting; cultivation of green manure crops; chemical fertilizers	Manure; sometimes human waste; composting; cultivation of green manure crops; chemical fertilizers
Weeding	Minimal	Required as the length of the fallow decreases	Intensive weeding required	Intensive weeding required	Intensive weeding required
Use of animals	None	Animal-drawn plough begins to appear as length of fallow decreases	Ploughing, transport	Ploughing, transport, postharvest tasks, and irrigation	Ploughing, transport, postharvest tasks, and irrigation
Seasonality of demand for labour	Minimal	Weeding	Land preparation, weeding and harvesting	Land preparation, weeding and harvesting	Acute peak in demand around land preparation, harvest and postharvest tasks
Supply of fodder	None	Emergence of grazing land	Abundant open grazing	Open grazing restricted to marginal lands and stubble grazing	Intensive fodder management and production of fodder crops

two being intensive types of land use (Boserup 1965; Meertens *et al.* 1995: 8, table 1; Table 6.3).

Forest fallow: plots of forest are cleared each year and cultivated for a few years followed by a fallow period of more than 20 years; bush fallow: shorter fallow than forest fallow from around six to ten years with varying lengths of cultivation in between fallow periods; short fallow: fallow lasts only a few years followed by a period of cultivation; annual cultivation: close to no fallow period is observed, if only for the few months between harvest and subsequent sowing; multiple cropping: most intensive system of land use because the same plot is cultivated by two or more successive crops each year, and fallow is (almost) absent (Boserup 1965, 9).

As stated above, farmers can, to a certain extent, be dynamic in their choice of adopting intensive or extensive strategies and indeed many intermediate or mixed land use types exist.

Boserup postulated the hypothesis in her model that an increased population pressure is the main agent for intensification of practice (Boserup 1965, 16), but others have indicated that economy, technology, ecology, and social restrictions can have an effect on the adoption of either an intensive or extensive land use strategy (Meertens *et al.* 1995,52). First, an example of how these variables can influence farmer's decisions is given based on one of the selected cultures from Murdock, the Sukuma from Tanzania. This example was chosen, because it is the only quantitative study available on crop husbandry practices based on the selected cultures from Murdock. Other cultures in this list (Appendix A1.4) have merely been described on an anthropological basis, rather than an ethnographic basis.

After the description of crop husbandry practices of the Sukuma, the variables from this study are used in combination with Boserup's initial land use types to develop an expectation for the West Frisian situation. The effect of each of the variables has been investigated in Tanzania based on small-scale farming communities (Meertens *et al.* 1995). This study revealed that ecology and social factors can drive farmers to intensive agriculture, such as during land shortages, warfare, or imposed policies by others (Meertens *et al.* 1995, 67). However, under normal circumstances, small-scale subsistence economies with the availability of a plough (*i.e.* economy and technology) show a preference for extensive land use. This is illustrated by the fact that as soon as restrictions such as war and policy were relieved in Tanzania, people immediately reverted back to extensive agriculture. The combination of availability of land and plough allowed them to cultivate larger fields, and letting them lie fallow, actually eliminating the need for manuring to maintain soil fertility (Meertens *et al.* 1995, 68-9). At low population densities, the farmers had land use strategies that were either extensive bush fallow or short fallow systems.

Building on the evidence of the case study in Tanzania and the examples provided by Boserup, two types of land use seem most applicable to small-scale crop husbandry, namely extensive bush fallow and short fallow. However, since only short fallow farming systems are characterized by the presence of a plough, this land use type seems most appropriate for West Frisia. The analysis of the West Frisian data will have to show whether this land use type, or perhaps a different land use type, is indeed most plausible.

Other aspects related to this short fallow land use include: fertilization with animal dung and household refuse/compost; intensive weeding; using animals for ploughing and transport; demand of labour for land preparation, weeding, and harvesting; and open grazing of animals (Boserup 1965; Meertens *et al.* 1995: 8, Table 1; Table 6.3). The use of animals for hard labour such as ploughing and transport has indeed been identified based on cattle bones in West Frisia (Chapter 5, section 5.4.7.4). Furthermore, open grazing of livestock was also postulated based on the vegetation reconstruction (Chapter 2, section 2.3.3), and animal husbandry practices (Chapter 5, section 5.3.5).

The concurrence of the other aspects, related to crop husbandry, is assessed in the following relevant sections.

6.3.1 Arable field size and crop composition

Arable fields

Considering the short fallow land use type as a prerequisite, parallels for field sizes of small-scale mixed farming communities were sought using the ethnographic work performed by Murdock (1981). Note however, that the definition of intensity of crop husbandry employed by Murdock is different than the definition by Boserup: Murdock considers crop husbandry with short fallow to be intensive, whereas in Boserup's model, only annual cultivation and multiple cropping are deemed intensive land use. The selection on Murdock's work therefore uses the prerequisites intensive agriculture1 on permanent fields, use of fertilization, crop rotation, or other techniques to ensure a short to no fallow period. In addition, the cultures selected should be cultivating cereal grains as their main crops.

The outcome of the selection has made it possible to further investigate the characteristics of these farming communities (Appendix A1.4). Narrowing the selection down to only the smallest settlement sizes (*i.e.* neighbourhoods and hamlets), the average size

Figure 6.2. Example of a garden kept near the main house in the Danube delta, Romania.

of arable land owned per household (with on average 6 people) accounts to 1.8 hectares, with a range of 1-3 hectares (Byrnes 1992; United Nations 1996; Shundi 2006; Nyasimi *et al.* 2007; Talensi-Nabdam n.d). Similar trends can be observed in eastern and central Europe (Sarris *et al.* 1999; Mathijs & Noev 2004). This total arable land size can be, and often is, subdivided into several smaller plots. In Sweden, individual field sizes related to small-scale mixed farms up until recent times never reached more than 1 ha in size (Ihse 1995). When rotation of crops is applied due to fallow periods, the arable field size required will increase (section 6.3.3).

In order to further assess the size of arable fields of small-scale mixed farming units, Romanian and Slovakian ethnobotanical research was employed, for reasons described in section 6.2.2. Romanian small-scale farming households (consisting of ca. 5 people) own on average 4.7 ha of land, of which approximately 2.5 ha consists of arable fields

Figure 6.3. Example of a garden kept directly adjacent to the main house in the Danube delta, Romania.

(Hajnalová & Dreslerová 2010, 183, 186). Large strips of arable land are subdivided into smaller plots with an average size of 0.01-0.2 ha in Romania (einkorn) and 0.17-0.4 ha in Slovakia (emmer) (Hajnalová & Dreslerová 2010: 173, 190). Such smaller plots could have been worked and sowed in a day.

Interestingly, none of the fields had clear demarcated boundaries, which, in the abundant presence of deer, wild boar, and bear, leads to ample losses of crops. For this reason, dogs are kept at the borders of the fields to reduce crop losses (Hajnalová & Dreslerová 2010, 173).

The acreage of arable fields in the Romanian Carpathian mountains is somewhat higher than the average value based on the selections of the cultures researched by Murdock, which may be due to the hilly terrain. Therefore, the average value of 1.8 ha is used further, but the subdivision of plots observed in both the selections on Murdock's work and eastern Europe will also be kept in mind.

The postulated arable land size would therefore have been used extensively under a short fallow strategy. However, several of the selected cultures (*e.g.* Sotho, Lepcha) also showed the presence of garden plots near to the house, which were managed more intensively and which mainly contained vegetables etc. (*e.g.* Bhasin 2011; Sotho n.d.). A similar phenomenon was also observed by the author in a rural village in the

Figure 6.4. Example of a garden further away (ca. 100m) from the village.

Danube delta of Romania (Figure 6.2-Figure 6.4), where an extensive crop production was combined with more intensive small-scale horticulture. Garden plots are usually tended to by hand, sometimes with the help of hand tools such as a hoe. Since these types of gardens occur in several small-scale communities around the world, the presence of garden plots cultivated in a more intensive manner is expected.

Bronze Age arable fields

Ethnography has given clear indications for an expectation of arable land size and use. For the Bronze Age of north-western European specifically, indications for these aspects of crop husbandry also exist. Two different major types of field system seem to exist in the Bronze Age: fields of various shape and size, and Celtic fields. The former fields are usually of varying size, which sometimes have borders but usually show no clear boundary demarcations. Examples of such fields are observed in Denmark, as well as in the western area and the river area in the Netherlands (Poldermans 1987; Bech 1993; Tegtmeier 1993, 119; Bech 1997; Jongste & Wijngaarden 2002; Robinson 2003). Fields which do show boundary demarcations were found in Denmark, evidenced by an ending of the criss-cross pattern (Figure 6.5).

Celtic field systems arise only in the later Bronze Age. They are composed of a checkerboard complex of fields of comparable size, possibly bordered by wattle work or hedges (nb. the earthen boundaries

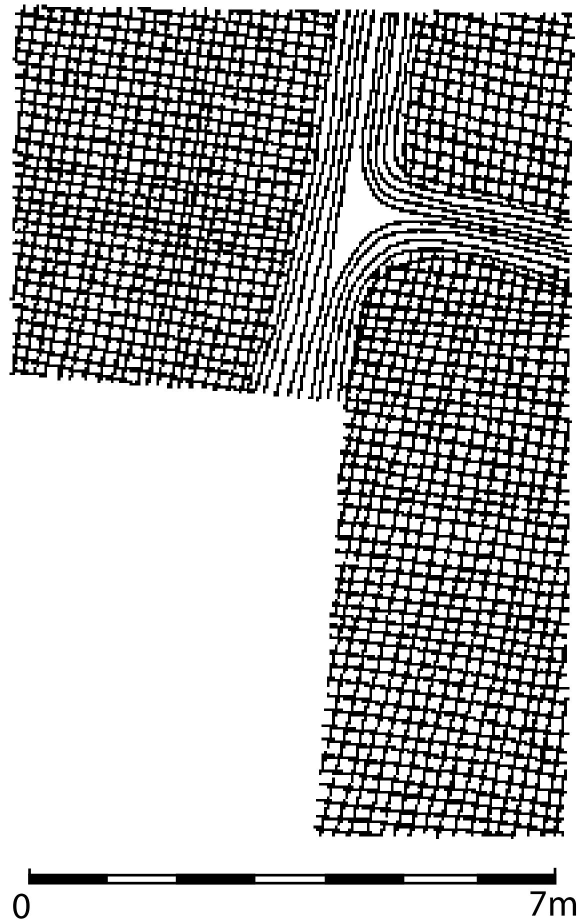

Figure 6.5. Overview of Bronze Age arable fields with boundaries (parallel lines) from Lusehøj, Denmark (from: Thrane 1984).

were only in use from the Middle Iron Age onwards) (Fokkens 1991; Tegtmeier 1993, 76; Fries 1995; Spek *et al.* 2003, 67; Arnoldussen 2012; Arnoldussen & Scheele 2014). The two different field systems seem to appear on different types of soils. Plots of varying shape and size mainly appear on clayey soils, as can be observed in the Dutch river area and Denmark (Tegtmeier 1993, 119). Celtic fields however, seem to appear mostly on sandy soils in north-western mainland Europe (*i.e.* Denmark, Germany, and the Netherlands) (Tegtmeier 1993; Spek 2003; Kooistra & Maas 2008).

In both field systems, plough marks can be identified, which reflect past ploughing practices. These marks are, however, only visible when certain conditions are met. First of all, plough marks are only visible when the plough perforates too deeply into the soil, thus scratching the layers underneath, producing a linear pattern of contrasting colours of soil (Figure 6.5). It can be imagined that when either perforation does not occur or soils are not of contrasting colour, plough marks will not be apparent. Since perforation into deeper layer is often irregular, sometimes only dependent on local soil conditions or inexperience of the person or animal ploughing, usually, no continuous plough marks can be discerned. The entire original size of arable fields is thus normally not visible during excavation, hindering the reconstruction of past arable field size.

Exceptions to this are for example continued ploughed areas in Noorderboekert, West Frisia (Knippenberg in prep.) and Haarlem, in the western Netherlands (Poldermans 1987), which cover an area of at least 120 x 60 m (pers. comm. S. Knippenberg), allowing for an estimation of minimum arable field size.

Arable field sizes in archaeology have been postulated for the Netherlands based on the amount of calories and inherent arable field sizes required per household. For the Neolithic, Bakels & Zeiler have hypothesized an arable field size of 0.6-2.3 ha for a household of 6 people (Bakels & Zeiler 2005). For the eastern parts of the Netherlands in the Bronze Age, an arable land size ranging from 2.0-3.9 ha was postulated to have been sown by one household practicing 50-100% arable farming on an annual basis (cf. Fokkens 1998, 142). The higher end of this estimation seems to be a on the large side compared with the examples mentioned above. The value of 2.5 ha provided by Brinkkemper (1993), for Iron Age wetland areas in the Netherlands, is more within range of the values above, but is based on protein requirement, not ethnographic parallels.

Based on the examples outlined above, it is expected that arable fields located on clay were of various shape and varying size. A total arable field size of 1-3 ha per household is expected, with an average of 1.8 ha.

Crops

Crops can be cultivated for multiple reasons, but the main reason assumed in this research is for human consumption. Other reasons for the cultivation of crops are discussed in section 6.4.8.4.

The main types of cultivated crops that are used in food production are cereals, pulses, legumes, and cultivated fruit, as well as oil containing plants (Stika & Heiss 2013, 349). Furthermore, the distribution of crops can be influenced by geography, time period, and climate. Therefore, in order to create an adequate expectation of the available crops in West Frisia, the focus will be on the crops that were available to farmers in the Bronze Age of western-central Europe (WCE), southern Scandinavia (SSc), and the North Sea coast (NSC) (Stika & Heiss 2013, 358-9). In Table 6.4, the relative dominance of cereals, pulses and legumes, oil-containing plants, and cultivated fruits is summarized for these three areas of Europe throughout the Bronze Age.

The most prevalent crops throughout the Bronze Age were emmer wheat and barley, which was mostly present in its hulled variety. Secondly, in some areas, spelt wheat, einkorn, and broomcorn millet were present. Less prevalent crops include foxtail-millet, rye, and oat. Non-cereal cultivated crops are less prevalent than cereals, being almost absent in southern Scandinavia and the North Sea coast, except for rare finds of field bean. In western central Europe, the available pulses and legumes include lentil, garden pea, bitter and common vetch, and field bean. Even less species of oil-containing plants were found, including linseed/flax, gold-of-pleasure, and opium poppy. Only one cultivated fruit was found, in the Late Bronze Age in western central Europe, which is grapevine.

In general, it appears that in the Early and Middle Bronze Age, little change in crop plant composition occurs in each area. However, towards the Late Bronze Age, more species are available and they become more frequent, although pulses, legumes, and oil-containing plants remain relatively scarce.

6.3.2 Soil preparation

The different manners of tending to arable fields in small-scale farming communities were mainly researched using the Romanian ethnobotanical example outlined in section 6.2.2.

Table 6.4. Overview of the available crops in the Bronze Age in West-Central Europe (WCE), Southern Scandinavia (SSc), and the North Sea Coast (NSC) (after: Stika & Heiss 2013, 358-9).

		EBA		MBA		LBA	
Taxa	**English name**	**SSc and NSC**	**WCE**	**SSc and NSC**	**WCE**	**SSc and NSC**	**WCE**
		cereals					
Hordeum vulgare	Barley	+++	+++	+++	+++	+++	++
var. *vulgare*	Hulled barley	+	+	+	+	+	
var. *nudum*	Naked barley	+	+/-	+	+/-	+	
Triticum dicoccum	Emmer wheat	++	++	++	++	++	++
Triticum spelta	Spelt wheat	+/-	++	+/-	++	+/-	+
Triticum monococcum	Einkorn	+/-	+	+/-	+	+/-	+
Panicum miliaceum	Broomcorn millet	+/-	+	+/-	+	+/-	++
Free-threshing wheat	Free-threshing wheat	+/-	+/-	+/-	+/-	+/-	+/-
Setaria italica	Foxtail millet	-	+/-	-	+/-	-	+/-
Secale cereale	Rye	-	+/-	-	+/-	-	+/-
Avena sativa	Oat	-	-	-	-	+/-	+
		pulses and legumes					
Lens culinaris	Lentil	-	+/-	-	+/-	-	+
Pisum sativum	Garden pea	-	+	-	-	-	+
Vicia ervilia	Bitter vetch	-	-	-	+/-	-	+/-
Vicia faba	Field bean	-	+/-	-	+/-	+/-	+
Vicia sativa	Common vetch	-	-	-	-	-	+/-
		oil-containing plants					
Linum usitatissimum	Linseed/Flax	+/-	-	+/-	-	+	+/-
Camelina sativa	Gold-of-pleasure	-	+/-	-	+/-	+	+
Papaver somniferum s.l.	Opium poppy	-	-	-	-	-	+/-
		cultivated fruit					
Vitis sylvestris ssp. *sylvestris*	Grapevine	-	-	-	-	-	+/-

+++=dominance, ++=subdominance, +=present, +/-=low amounts, -=absent. Adapted from: Stika and Heiss 2013, 358-9)

Tillage

Tillage of fields, or the preparation of arable fields by disturbing the soil, can take several forms, but in small-scale subsistence economies, the means are often limited. Therefore, often only digging sticks, hoes, rakes, and wooden ploughs[10] are used, sometimes in combination with metal parts.

Ploughing

Ploughing is often applied to larger fields directly after harvest in autumn. In this manner, any leftover stubble is worked into the soil in order to retain soil nutrients. When the weather or other factors do not allow for ploughing in autumn, it is postponed until the next spring. When crops are sown in spring rather than in autumn, fields are ploughed for a second time or harrowed directly before sowing. This ploughing only needs to occur in a very shallow manner (max 15 cm deep) (Hajnalová & Dreslerová 2010: 175, 187, 194), since spring crops do not require deep furrows for sowing. After sowing, the seeds are covered manually with earth, or by harrowing or raking (Hajnalová & Dreslerová 2010, 177).

Ploughing speed depends on the cattle pulling the plough. A pair of cattle in Romania plough 0.1 ha/day, but these cattle are larger than Bronze Age cattle and they often plough in hilly terrain (Hajnalová & Dreslerová 2010, 176). Experiments with smaller cattle have been performed in Denmark using Iron Age sized oxen instead, which are actually even smaller than Bronze Age cattle. Such a pair of such oxen can plough 0.35ha/hr (Hansen 1969), which means that in a day, a much larger area could be ploughed. However, these results are from sandy/loamy soils, which are much less resistant than clayey soils, the latter of which are the kind of soils relevant for West Frisia (cf. van Zijverden forthcoming). Therefore, the speed of Bronze Age cattle will probably lie somewhere between the values 0.1-0.35 ha/hr.
Ploughing in prehistory often occurs in a criss-cross fashion. Although not often practiced in present-day farming communities, one example from Ethiopia exists where people still use the ard to plough furrows in a criss-cross fashion (Temesgen *et al.* 2011). Parallel furrows cannot be ploughed in too close proximity, since the plough would slide into the previously made furrows rather than follow its own path. Therefore, perpendicular ploughing is practiced, to ensure the largest area possible of the arable field is worked (Temesgen 2007, 7).

Hoeing and raking

Smaller fields are often tended to by means of hoeing or raking. The stubbles from the previous year are removed by either hoeing or stubble burning, after which the field is raked. Subsequently, the hoe is used to produce furrows for sowing, after which the rake is used to cover the seeds (Hajnalová & Dreslerová 2010,175-6).

No tillage

On very heavy clay soils, sometimes no tillage (*i.e.* ploughing) is applied, under the condition that flooding of the land takes place during winter. Sherratt (1980, 318) states: "*Where soils are subject to winter flooding and summer desiccation, the deep cracking caused by drying-out would provide natural aeration and make them practically self-cultivating*." The winter floods would regenerate the soils with nutrients, making manuring a redundant practice for these soils. This type of crop cultivation would, however, only be combinable with spring sowing. In the USA, the no tillage strategy produced the highest crop yields on the very heavy clayey soils present there (Chen *et al.* 2004). Additionally, Rasmussen (1999) finds similar results for arable fields in Scandinavia.

Burning

A fast and low-cost method with a low labour input is the burning of crop residue (*i.e.* stubble) from the previous crop (Kumar & Goh 1999, 230); burning of arable fields can form an efficient tool for small-scale farmers. Stubble burning is practiced shortly after the harvest has been completed, to remove remaining stubbles from the previous crop stand (Williams *et al.* 2013; Burning residues 2016). This form of

10. Ploughs used in the Bronze Age are called ards (see Appendix A1.9). These types of wooden ploughs only tear the soil, they do not turn it.

crop residue management is much more efficient than incorporating entire and elaborate amounts of crop residues into the soil, especially when high amounts of crop residue are present, which hamper the pre-sowing ploughing and subsequent sowing of the following crop (Williams *et al.* 2013: 6). After burning, the resulting ash after burning is either left on the surface or worked into the soil. Advantages to stubble burning are the removal of crop weed seeds, the facilitation of sowing of subsequent crops, and the improvement of management of pests and diseases (Williams *et al.* 2013: 6, 24; Burning residues 2016). When a field is intended for burning however, it should not be grazed to ensure that there is enough stubble for the burn. Another adverse effect of stubble grazing is that weed seeds are being trampled into the soil, reducing the chance that they are destroyed in the stubble burning process (Burning residues 2016).

Figure 6.6. Stubble burning in France (photos courtesy of C. Vermeeren).

Stubble burning is distinctly different from slash-and-burn practices, where forest is burnt to clear fields. Burning of stubble is still practiced in some areas of Europe and the United States today (Hajnalová & Dreslerová 2010, 176; Ascoli & Bovio 2013; Manitoba 2016), but was much more common in the not too distant past (Figure 6.6). Apart from efficiency reasons, stubble burning can also be a necessity, since in areas where the soil consists of very heavy clay, it can prove impractical or even nearly impossible to plough the land. Examples of this can still be seen in Manitoba, USA, were farmers prefer to practice stubble burning rather than ploughing when policies allow it (Chen *et al.* 2005).

In fact, when executed properly, a regime of stubble burning can produce spring barley crop yields that surpass yields of spring barley grown on fields with ploughed under stubble, or manured fields (Badaliková & Hruby 2006).

Fallow

Both wheat and barley are intolerant of continuous cultivation, so land needs to be left to lie fallow. Alternatively, rotational cropping can be applied, or a combination of fallow and rotational cropping, all with the aim of regenerating the soil. The practice of letting fields lie fallow after the harvest can occur after one or more years of cultivation. As postulated in section 6.3, the short fallow system is considered the most plausible type of land use for small-scale mixed farmers. In these systems, plants are cultivated for a number of years, after which subsequently one or two years of fallow follow. Fallow fields can for example be used as pastures for livestock, decreasing the extra amount of pasture needed to sustain animals.

6.3.3 Cultivation

Sowing

Sowing practices

Sowing of crops can be performed in several different manners. Two of the main methods include broadcasting and planting in furrows. Planting in furrows requires the farmer to put each individual seed into the soil one by one, or, alternatively, funnel-like instruments can be attached to the plough to facilitate sowing (Steensberg 1971, 245). This is applied for crops with relatively large seeds, such as pulses. Alternatively, a combination is possible, wherein furrows are sown by throwing multiple seeds along the furrow with or without being combined with animal dung (Steensberg 1971, 249-50), which also occurs with several wheat species (Steensberg 1971, 250). However, in general, for cereals crops with small grain kernels such as emmer wheat, it is more applicable to cast multiple seeds in furrows or by broadcasting seeds (*i.e.* or scattering seeds by throwing them over a large surface), since their grains are hard to handle individually over large areas (Steensberg 1971: 250, 253; Lerche & Steensberg 1983, 229; Peña Chocarro 1995, 97, 117; Hajnalová & Dreslerová 2010, 177). After sowing, the seeds are for example covered by harrowing soil over them. The amount of seeds sown by broadcasting is roughly 100-200 kg/ha in Romania (Hajnalová & Dreslerová 2010, 176), and a comparable volume (150-250 kg/ha) is observed in Asturias, Spain (Peña Chocarro 1995, 118). When the expected arable field size of 1.8 ha per household is applied, this means that a family would sow around 180-360 kg of sowing seed per year based on the Romanian example.

Sowing seed

Seeds needed for sowing the next year are retained from the harvest. Only the largest and most well-developed seeds are selected for this purpose, since it ensures a good quality of sowing seed (Hajnalová & Dreslerová 2010, 176). The amount of seeds retained is preferably twice the number of seeds needed for planting: harvests can fail and in this manner, it is ensured that enough seed is left to sow the following year. In Romania, 200-400 kg of seeds are retained per harvest, when possible (Hajnalová & Dreslerová 2010, 184).

Maslin

Crops can be sown as one species per field, or can be combined with another crop on the same field. When two or sometimes three crops are mixed by casting multiple seeds in furrows or during broadcasting, this is called a maslin crop. Maslin crops are used as risk-reducing strategy, since different species have different tolerances for different environmental conditions. Due to this difference in tolerance, and because the farmer cannot predict the conditions of the following year, he ensures some level of success by mixing two crops in one field (van der Veen 1995, 335; Bakels 2012). Although the practice of sowing maslin crops is a known phenomenon from ethnography and history (Slicher van Bath 1963; Bieleman 1992), it is notoriously hard to prove for prehistory, since mixing of remains from both crops can occur at multiple stages of harvest processing (van der Veen 1995, 335). Still, it is possible to identify some aspects based on reasoning.

Cereal crops cultivated solely for human consumption can indeed have been sown as maslin. However, we are considering small-scale mixed farming communities, who will most likely have used or recycled every residue. When straw of cereals has been used as supplementary fodder for animals unable to graze by themselves for whatever reason, a maslin crop will not always be the best option.

The two main types of cereal cultivated in West Frisia are emmer wheat and barley (see section 6.4.1). The straw of emmer wheat is unsuitable as fodder because it is sharp and tough (Hajnalová & Dreslerová 2010, 187), but barley straw is very suitable (Bakx 2011, 64 and references therein). If these two crops were mixed in fields, it would have been very hard to ensure the correct fodder, since wheat and barley straw would have had to be separated again in the field. Also, straw of different species may not ripen at the same moment, resulting in different or bad quality straw of these two cereals. Therefore, it is more likely that emmer wheat and barley were cultivated in separate fields, and perhaps only became mixed during further harvest processing steps.

Rotation

Rotation of crops involves planting different crops in the same field in subsequent years, often followed once every couple of years by a period of fallow. Wheat, barley, pulses, and especially flax are very intolerant of continuous cropping (Hajnalová & Dreslerová 2010, 195), these crops are usually sown after one another. Pulses are known for their soil regeneration properties, due to their ability to fix nitrogen through their root-systems. They are therefore usually planted after a few years of cereal crops to replenish possible nutrient deficiencies. An alteration of autumn sown plants with spring sown plants is also a rotational strategy which can be applied.

Weeding

Weeding of crops is a practice with varying levels of incorporation into the crop husbandry regime. The level of weeding of a field depends on the distance from the settlement, available time and labour force, and intensity of land use. Based on Boserup's model of short fallow systems, it was expected that weeding would be performed intensively. In Romania however, crop weeds are usually left in the field, even up to the point where the researching ethnobotanists mistook the arable field for a fallow field (Hajnalová & Dreslerová 2010, 193). However, such plots were far away from the settlement, and these crops were used for animal fodder. Romanian farmers believe, in contrast to common opinion, that weeding disrupts the calm life of the crop and that the presence of weeds ensures the moisture of the soil. When weeding is done in the field, it is mostly done one to three times per spring, and only by hand. The only weeds consistently removed are thistles (*Cirsium/Carduus* spec.).

Another interesting observation made by the ethnobotanists in Romania related to weeding, which should actually be considered the first step of harvest processing, was the removal of weeds during and after harvest, especially when the straw is valued. Instead of weeding the field while the plant is growing, weeds are removed by hand during harvesting by "combing" them away using the fingers, from a bundle of reaped crops at a time, when weather conditions are good (Hajnalová & Dreslerová 2010, 177-8). When the weather is forcing the people to make more haste harvesting, bundles of cereals are taken to the village, with weeds still attached. They are then removed after the harvest in a similar manner, and bundles of clean crops are taken into storage. The weeds are used as animal feed (Hajnalová & Dreslerová 2010, 178).

Harvesting

Harvesting practices

Harvesting in small-scale subsistence communities usually occurs by hand, often with the use of tools. In Romania, two types of sickles were in use: a smooth bladed sickle and a sickle with a toothed blade. The preference for either of these sickles was different for each farmer and did not depend upon family or village traditions. However, when farmers who normally use one type of sickle were given the other type, the tendency for uprooting occurred (Hajnalová & Dreslerová 2010, 177). Although uprooting can be the result of an unpractised hand, it can also be a deliberate harvesting technique. The plant is pulled out of the ground entirely by hand, making the most of the stem for possible further uses such as animal fodder, raw material for basketry or thatching, or fibre (Ibanez *et al.* 2008; Hajnalová & Dreslerová 2010: 177, 189). A similar result can be obtained by harvesting low to the ground, which is also the case in Romania and Slovakia, where reaping takes place 10-15 cm above the ground (Hajnalová & Dreslerová 2010, 177). The ears are removed from the stems, after which the culms are dried for animal fodder and the ears are kept for post-harvest processing. Besides uprooting or reaping low on the stem, other harvesting methods include: ear-plucking, thus leaving the stems in the field and reaping high on the stem, when the length of the straw is not important. Other methods can be applied to remove ears from the stem in the absence of (appropriate material for)

Figure 6.7. An alternative harvesting method: the mesorias; a: The harvesting tool called mesorias (Peña Chocarro 2014, 104, Figure 4.22); b; The wooden sticks are connected by a string or leather; the sticks are pinched around crop stems and moved upwards to pinch off crop ears (from: McClatchie 2008).

sickles. One such an example comes from Asturias, Spain. It is called a *mesorias*, or reaping clamp, which is a set of large wooden sticks (approx. 1 m in length) connected by a small string at one end (Figure 6.7a; Peña Chocarro 2014, 104). By pinching these sticks on the stems of the crop and moving in an upward fashion, ears are pinched off and collected in baskets (Figure 6.7b; Ibanez *et al.* 2008, 190-1).

Harvest speed

The speed with which people using sickles are able to harvest averages around 0.02 ha/hour (Hajnalová & Dreslerová 2010, 177). In contrast, people using reaping clamps can harvest around 0.02 ha/day, which is comparable to uprooting (Halstead 2014, 108). When one person needs to harvest an entire field of 1.8 ha, this may take several weeks. Since this takes too long to complete before deterioration of the crop, more people are required to complete this practice. This demand for labour during harvest time supports the expectation of short fallow land use in small-scale farming communities.

Harvest yield

The einkorn harvest in Romania yields approximately 2t/ha. Emmer harvests from Slovakia average around 1.77 t/ha, with a range of 0.73-3.80 t/ha (Tempír 1976), which is in concurrence with the yields of experiments performed in Bohemia, Czech Republic, which average around 1.7 t/ha (Beranová 1987). It is unknown whether these examples entailed spring or autumn varieties, and a modern experiment from eastern Austria shows the possible difference in yield: spring emmer yielded 2.7 t/ha, whereas winter emmer yielded considerably higher at 3.8 t/ha (Grausgruber *et al.* 2004).

Barley grown on unmanured arable fields at the research station at Rothamsted, Britain, yielded on average 1.2 t/ha (Barker 1985, 51). Spring barley on a medium sized organic farm in Sweden has a yield of around 1.0 t/ha (Östman *et al.* 2003). Thus, on average, the yield of barley averages around 1.1 t/ha. For the postulated arable field size per household of 1.8ha (section 6.3.1), this would mean an overall

	Post-harvest processing steps								
	1. threshing	2. raking	3. first winnowing	4. coarse sieving	5. first fine sieving	6. pounding	7. second winnowing	8. second fine sieving	9. sorting
	Steps required for processing after storage for daily consumption								
Storage as sheaves/ears	x	x	x	x	x	x	x	x	x
Storage as spikelet	completed before storage					x	x	x	x
Storage as grain	completed before storage							(x)	x

Figure 6.8. Overview of post-harvest crop processing steps and of which steps need to be conducted before daily consumption, depending on the manner in which the grain is stored (adapted from: Fuller *et al*. 2014, figure 4).

yield of around 3,000 kg of emmer wheat or around 2,000 kg of barley per year.

Harvest losses

Losses of harvest can occur when sown seeds have not germinated, during harvest, because of pests (*i.e.* rodents, birds, mammals, insects), and because of transport and processing. Romanian harvest losses vary from 0-40% (Hajnalová & Dreslerová 2010, 181), and in the Czech Republic it is estimated to be around 17-20% (Rozsypalová 2000, 69-70). When 20% loss is assumed, this means that the remaining yield of harvest would be around 2,400 kg of emmer wheat or 1,600 kg of barley per household per year.

Crop yield factor

The crop yield factor investigates the ratio of input of grains for sowing and the output of grains of subsequent harvest, basically to assess the efficiency of crop husbandry. In archaeological experiments, the crop yield factors may vary from 1:7-1:59 (Reynolds 1987).

In Romania, around 180-360 kg of seed is sown per household (see above: sowing practices). The yield, after losses of 20%, lies around 1,600-2,400 kg depending on the crop species. The crop yield factor would thus be ca. 1:8. This crop yield factor value is slightly lower than the 1:10 factor proposed by Fokkens (1991, 141), and the input of grains is higher (*i.e.* 100-200kg vs. 60 kg). This higher input is probably due to the fact that seeds are broadcast in Romania, which requires relatively high amounts of grains for sowing compared to for example planting in furrows. Nonetheless, the Romanian values are used for further interpretation, because they reflect observed values in small-scale mixed farming communities. Note that this crop yield factor value is much higher than the normally assumed value and applied values based on medieval crops (1:3 – 1:4, from: Slicher van Bath 1962, 18).

6.3.4 Handling and related locations

Post-harvest crop processing

Before the harvest can be employed for consumption or other uses, multiple crop processing steps need to be undertaken, especially when hulled grains are concerned, such as in West Frisia (cf. section 6.4.1). These steps include: drying of the harvested crop (often in the field); threshing to release the grain and chaff from the stem; collecting the threshed grains; and a series of winnowing and sieving of the grain on different mesh sizes to remove unwanted weeds and other cereal plant parts (cf. Hillman 1984; Figure 6.8). Finally, grains are dried (in wet climates sometimes with the use of fire) to avoid spoilage in storage. All of these steps can be recognised in ratios or occurrence of remains in archaeological assemblages, although some steps are more distinct than others (cf. Hillman 1984; Figure 6.8).

Several factors influence how crop processing is practiced as well as the degree to which this occurs. Factors affecting crop processing include, amongst others, climate, available man-power, and cereal type. Climate can influence post-harvest processing in the form of rain. Harvesting needs to occur in a dry period of the year, since storage and subsequent processing requires a dry crop. Therefore, when bad weather is imminent, farmers may choose to harvest quickly and perform most of the crop processing steps indoors. Conversely, good weather allows farmers to process in the field, returning only the essential parts of the crop to the settlement and leaving the remaining stubble in the field. Of course, this practice also depends on how many people are available to help with the harvest. If the weather is favourable for processing in the field, but not enough people are available to perform this bulk task, the harvest may still become stored in a relatively unclean manner (pers. comm. C. Stevens). The type of cereal grown is also of influence to crop processing. In wet climates, grain is prone to spoilage in storage due fungi infections or germination before further use. Susceptibility to infection can be lowered by cultivating hulled cereals. Hulled cereals are protected against most infections due to their chaff, so they are often stored in bulk in their chaff. This storage can occur whilst still attached to the sheaf, as whole ears, or as individual spikelets (*i.e.* bulk store: Hillman 1984, 8; Figure 8.6). Another method to reduce the chance of spoilt grain is artificial drying with the use of fire before storage (Hajnalová & Dreslerová 2010, 187 and references therein).

As mentioned, the vast majority of crops in West Frisia were hulled (see section 6.4.1). Therefore, only hulled cereals are discussed next. For the preparation of food for one or more days, dried, hulled cereals were removed from the bulk store and processed further (Hillman 1984). The final processing steps from storage to consumption are expected to have occurred on a near-daily basis (Figure 8.6). These processing steps, which will have occurred hundreds of times each year, will thus be far better reflected in charred assemblages on a site than the annual harvest bulk pre-processing steps, which occurred only once, and sometimes not even at the settlement (Peña Chocarro 1995, 102-107).

The social organisation of harvesting can also be recognised in archaeological assemblages through the manner in which cereal is stored. It has recently been postulated that when limited time and man-power are available during harvest, crops are stored

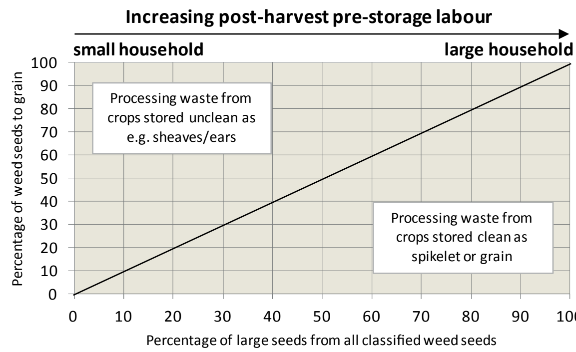

Figure 6.9. Graph depicting the social organisation during harvest based on the ratios of weeds and grains in an assemblage. The ratios of weeds and grains, as well as the size of the weeds inform about the range of processing steps undertaken from storage to consumption. Crops brought unclean to the settlement require more processing at the settlement and this will result in more and different processing waste than relatively clean crops (cf. Figure 6.8). The storage of clean or unclean crops is linked to the availability of time and man-power during harvest, and therefore social organisation. Having clean crops in storage is related to large(r) households, whereas storage of unclean crops is related to small(er) households (after: Stevens 2003, 73, fig. 7).

in a relatively unclean state (*i.e.* in sheaves or ears), and pre-storage processing is then limited (Stevens 2003; Fuller *et al.* 2014). Conversely, a relatively clean crop in storage may reflect the ample time and man-power available during harvest time, allowing for bulk processing of the harvest entirely down to spikelet form. Since daily processing is expected to have been the reason for the majority of charred crop remains at a settlement, the range of processing steps undertaken from storage to consumption can inform about the available time and man-power during harvest. For example, if indeed the crop was stored relatively unclean, the assemblage of charred remains on a settlement should reflect more processing steps and different inherent processing waste than when grain was stored in spikelet form. Limited time and man-power, and therefore social organisation during harvest, might then be reconstructed based on certain ratios of weeds and grains in archaeological samples (Stevens 2003; Fuller *et al.* 2014; Figure 6.9).

What is clear from Figure 6.9 is that smaller households can be recognized in archaeological assemblages by relatively high percentages of (small) weeds. Weeds, and especially small weeds are removed during the early stages of post-harvest processing (Hillman 1984; Figure 6.8), so they will be most prominent in daily post-storage processing of unclean cereals. By the same reasoning, archaeological assemblages reflecting the processing of clean cereals from storage by larger households will contain relatively many cereal grains, and relatively many large weeds, since these are removed during later stages of harvest processing (Hillman 1984; Figure 6.8). Small households will therefore appear in the upper left region of a graph such as in Figure 6.9, whereas larger households will appear in the lower right region. Small households will thus reflect the possession of limited time and man-power, whereas the opposite might be regarded as the reflection on large(r) households. Although both household sizes cannot be directly translated into family size, they do allow for the identification of relative differences between houses and their (post-) harvest practices.

Storage

Types of storage area

Storage areas for the harvested cereals needs to be dry, well-ventilated, and of a size that is sufficient for maximum possible harvest yields, as these may vary annually. In addition, cereals stored in storage areas should be protected from pests. In Romania and Slovakia, grains are stored in wooden chests, or, in the past, they were stored in wattle-and-daub containers or hollowed-out tree trunks. These were stored in the attic above the living area of the house (Hajnalová & Dreslerová 2010: 184, 190). Cereal grains can be stored in this manner for two to three years. Alternatively, but only sporadically, grains can be kept in textile bags, but this only allows storage for shorter periods of time (Hajnalová & Dreslerová 2010: 185, 190).

Bronze Age examples of storage possibilities for cereals include wooden containers, ceramics or leather sacks hung from the ceiling, such as was observed at several locations in Bronze Age Denmark (Andreasen 2009, 55 and references therein). Often, the living area and also potential storage location of grains in Bronze Age Denmark was thought to be in the western part of the house (Andreasen 2009, 55). Harvests can also be stored without containers in a silo underground, but in areas with a very high water table this practice is not expected.

Other archaeological examples of storage locations mostly include separate outbuildings such as granaries, in which the grain is elevated from the ground.

Size of storage area

When it is assumed that the emmer yield lies around 1.7 t/ha, losses not included, and the harvest is stored in spikelet form (like in Romania and Slovakia), the maximum space necessary for emmer storage would be around 2.2 m^3/ha (using the weight to volume conversion of wheat as a guidance; Weight to volume conversion 2016). Similarly, if the yield of barley is considered to be around 1.2 t/ha, an additional maximum of 2.0 m^3/ha would be required to store barley (using the conversion values of barley grains a guidance; Weight to volume conversion 2016).

Based on the ethnographical parallels, a small farm would cultivate around 1.8 ha, which means that a maximum of 4 m^3 of space would be required per household to store the grain. Storage in ears or sheaves would require a much larger area.

6.3.5 Arable field soil conditions and locations

Environmental conditions

The growth of a plant is dependent on the fertility of the soil as well as other abiotic environmental characteristics. Water availability and adequate temperature are required in order for a seed to germinate, and remain important environmental factors throughout its life: drought and cold are conditions in which only specialized plants can survive. Salinity and acidity are two further environmental factors which can limit plant growth; most plants require fresh, non-acidic water conditions in order to grow. Furthermore, amongst other important nutrients in the soil, nitrogen can affect plant growth positively or negatively, depending on the species. Finally, phosphate is important as an energy provider for the plant. These various abiotic factors all influence the growth of a plant. Generally, the most beneficial growing conditions for most plants are moist soils, warm temperatures, a pH of 5.5-7.0, and ample available nitrogen and phosphate.

Soil fertility

The fertility of a soil is not only expressed in the amount of nutrients in the soil. Fertility is basically the characteristics of a soil in relation to the accessibility to the abiotic factors mentioned above. Fertile soils are characterized by being able to retain enough moisture for plant growth, but also allow enough water to seep through to deeper levels in order to prevent rotting of roots. Nutrients should also be retained in the topsoil to increase their accessibility to plant roots.

Sandy soils are usually deemed unfertile due to their loose structure and their inability to retain enough water and nutrients for a plant. Manure is often added to sandy soils to improve their water and nutrient retaining properties. Most clayey soils on the other hand, are fertile due to their very fine structure and ability to retain enough water and nutrients. The fertility of clay soils however, depends on the structure. Although rich in nutrients, heavy clay soil can also be classified as unfertile because access to water and nutrients is prevented by its dense structure. Manure is often added to improve/aerate the structure of clayey soil, but not necessarily for the addition of nutrients.

Manuring

Manuring is a practice which entails the application of (plant or animal) fertilizer to an arable field in order to improve the fertility of the soil. Fertilizing a soil can include adding nutrients to the soil, improving its aeration, its water retention, and its crumbling characteristics, which are all necessary soil characteristics for adequate plant growth (Lynden & Bakker 1990, 215-30).

Manuring is however, not always practiced, since it is dependent on the available time, labour force, condition of the soil, and presence of (enough) domestic animals. In Spain, the quantity of manure produced by domestic animals was insufficient to manure all the fields. Different fields were therefore manured in different manners and emmer wheat fields were not manured at all because this would cause lodging (*i.e.* flattening to the ground due to wind and rain) of the crop (Peña Chocarro 1995: 93-4, 113). In another area of Spain, animal manure was mixed with household waste, plants, and ash during winter (Peña Chocarro 1995, 94). In Tanzania, farmers only applied manure to the fields when forced to intensify their crop husbandry regime, reverting back to no manuring directly after colonial pressure was released. When abundant land is available, letting fields lie fallow is preferred over manuring, since the practice of manuring is very high in labour input (Meertens *et al.* 1995, 77). Farmers would need to apply 7.5-20 t/ha of manure to their fields; an investment in time and labour many could not muster. Even today, people in Tanzania usually do not apply manure to their fields, stating that the clayey soils are fertile enough (Meertens *et al.*1995, 78).

Romanian farmers traditionally used farm-yard manure for garden plots and for spring barley. Manure was transported to the fields and ploughed into the soil as close after the previous harvest as possible. One cow was said to produce just enough manure for 1 ha, and when enough manure was available, it could also be used for meadows. Still, manure was not applied to all arable fields, especially when the crop was not primarily grown for cereal grain but for its straw (Hajnalová & Dreslerová 2010, 176).

In Slovakia, many plots are not manured either. When manure is applied, it is usually for a specific crop and only takes place every four years, depending on the crop rotation strategy. Alternatively, during fallow years, sheep pens could be circulated around the fallow fields to manure the plot in that manner (Hajnalová & Dreslerová 2010, 189). Clearly, the use of animal dung and household waste for manuring expected based on Boserup's model on short fallow systems, is not applied everywhere.

Location of arable fields

Similar to arable field size, the location of arable fields can be dependent on many factors, including available suitable land, population density, technology, and social organisation. In times of social conflict for example, farmers are known to manage their arable land closer to the settlement than when no immediate threat exists (Meertens *et al.* 1995; section 6.3). Furthermore, a high population density and an inherent decrease of appropriate arable land may force people to cultivate fields closer to the settlement. Finally, choices made by farmers whether or not to incorporate certain technologies, such as manuring, may influence the distance of fields from the settlement due to practicality of labour and transport. In Europe in general, China, and Pakistan, the average distance of arable plots from the farm ranges from 0.3 to 2.0 km (Chisholm 1968, 46). In the Carpathian mountains of Romania, fields of subsistence farmers are located as close to the village as possible and are no more than half an hour walk away (Hajnalová & Dreslerová 2010, 172), which would translate to a maximum distance of 2.5 km from the settlement. This value is concurrent with the observations made by Chisholm, which range from 0.7 to 2.5 km (1968, 46).

6.3.6 Seasonality

Ploughing, burning, stubble grazing, manuring, weeding season

Ploughing occurs either once or twice a year. After the harvest, somewhere in the period from August to October, fields may be grazed by livestock, after which the fields are ploughed relatively deeply in order to remove the remains of the previous crop. Alternatively, stubble is burned. Manuring of fields usually occurs directly after harvest and is ploughed into the soil with the autumn ploughing. Spring sowing requires additional ploughing or harrowing, albeit more shallow than in autumn, which occurs as close to sowing as possible, somewhere from March to April. Weeding might occur one to three times in spring, depending on field location and land use intensity (Hajnalová & Dreslerová 2010, 176-7).

Sowing and harvesting season

Cereal crops can be sown during two periods of the year: in autumn or in spring. Autumn sowing involves sowing the seeds before the winter, in September-November, in which the seed lay dormant (only frost tolerant varieties) until germination in early spring. Cereals sown in autumn are called winter cereals, and experience a longer growing season. Therefore, the advantages of these cereals are that they have a high yield, and they can be harvested early in the year (June-July) (United States 1997).

Summer cereals on the other hand, are sown in early spring (February -March) after the worst wetness and cold of the winter have passed. These cereals have a shorter growing season and often a lower yield than winter cereals, and are also harvested later in the year (late July-early September) (United States 1997).

6.3.7 Summary and additional main components

Crop husbandry practices were researched with the aid of ethnographical and ethnobotanical parallels, which has resulted in general characteristics of such practices in small-scale mixed farming communities. The land use is usually more or less extensive, under a short fallow regime. In addition, farmers have small garden plots which they work more intensively. The size of the arable fields ranges from 1-3 ha per household, with an average of 1.8 ha, and this arable land is often divided into smaller plots. The shape and distribution of such fields is expected to consist of a system of fields of varying shape and size; a Celtic field system, as observed on the Pleistocene deposit areas in the Netherlands, is not presumed. Based on both ethnography and archaeology, it is clear that fields need not necessarily possess clear demarcations.

The crops available during the Bronze Age mostly consist of cereals. Based on comparisons with north-west European areas, an emphasis on hulled barley is expected, followed by emmer wheat. Furthermore, minor additions of spelt wheat, einkorn, broomcorn millet, and free-threshing wheat can be expected. Pulses and legumes are scarce, and it is not expected that many species are present, perhaps only in the Late Bronze Age. From the oil-containing crop plants, linseed/flax and perhaps gold-of-pleasure might be present.

Arable fields are ploughed in autumn, and, in the case of postponed ploughing and/or spring sowing, they can (also) be ploughed in spring. In spring, the ploughing occurs at a more shallow level than in autumn. Ploughing occurs by using a pair of cattle for traction, which could have been either cows or oxen. Smaller fields or gardens are worked by hand using hoe and rake. Alternative or even complementary methods to ploughing may include no tillage (under the influence of flooding in winter and breaking of the soil in summer) or stubble burning after harvest. Finally, land can be left to lie fallow for a few years, in order for soils to regenerate. In the short fallow system assumed here, fallow periods last one or two years at most.

Sowing of crops is expected to be performed by sowing multiple species in furrows or by broadcasting, due to the fact that their relatively small seeds are hard to handle over large areas. Per household, it is expected that on average 270 kg of grain is sown each year, during spring or autumn. The best grains are retained from the previous harvest to ensure a good quality sowing crop. The presence of maslin crops is an option, because they allow the farmer to spread the risk, which might be helpful in a dynamic environment. However, when it is assumed that farmers used crop residue for other purposes, maslin crops will have prevented the adequate separation of straw for animal fodder (barley) and for raw material (emmer wheat). Weeding is usually performed several times during the growth of the crop, and rotation of crops can occur by alternating cereals with pulses and fallow periods.

Harvesting is often performed by low reaping or uprooting, and will be performed simultaneously by multiple people. Harvest yields are expected to lie around 3,000 kg for emmer wheat, or 2,000 kg for hulled barley. These values are on an annual basis per household. The crop yield factor (*i.e.* input vs. output of sowing) for small-scale farming communities lies around 1:8, after harvest losses. Harvest losses can be severe and amount, on average, to more than 20%, due to transport and processing procedures.

Harvesting processing is mostly dependent on available man-power and time, and these factors influence whether crops are stored as sheaves, ears, or spikelets. The difference in how grains are stored can thus inform about the original harvesting conditions and possible variation in practice between households or settlements.
Storage most often occurs indoors above the living area of the house, since dry, elevated, and well-ventilated storage space is required. Also, the valuable staple crops can be easily guarded and accessed for further processing. The grains of the sowing seed may have been kept in wooden or wattle-and-daub containers or something similar to keep pests out and to ensure longer storage life. Cereals for consumption may have been kept in textile containers or containers made of a more sturdy material. Storage in ceramic containers might also be a possibility. The total storage area for grain in spikelets for one household measures around 4m^3, with higher demands for grains stored in sheaves or ears.

Many environmental conditions can affect a growing crop, of which water, temperature, salinity, acidity, and nitrogen are amongst the most important factors. Ideal soil characteristics for cereal growth include a moist soil with an average pH value of 5.5-7.0, and high in nutrients (especially nitrogen). Soil fertility is achieved by a combination of soil characteristics and availability to the environmental factors. In clayey soils, manuring may have ensured fertility of the soil, not by adding nutrients, but by aerating the soil and thus increasing the accessibility of nutrients to crops. The location of arable fields is normally relatively close to a settlement and they are rarely situated more than 2.5 km away.

Most of the expected aspects related Boserup's short fallow land use system are consistent with the ethnographical small-scale crop husbandry practices. However, as is clear from the Romanian example, weeding and manuring may not always be applied to a high extent.

The system is very comparable to most practices, so it will be the employed model for comparison with the West Frisian data.

Finally, also in this chapter the detailed investigation of crop husbandry practices has brought forth an additional main component, in this case regarding post-harvest field tending. This main component is added to the list of main components of the current model, and is challenged in section 6.5:

(8) Stubble burning may have been applied to clean arable fields after harvest for the subsequent sowing season.

6.4 WEST FRISIAN DATA ANALYSIS

This section is focused on the analysis of the West Frisian data, keeping in mind the different basic aspects of crop husbandry recognized in section 6.2 and 6.3. The analyses presented here are performed on both old and new data, and include both conventional archaeobotanical analyses such as the assessment of crop composition, seasonality of sowing, harvesting height, and arable field soil conditions, but also some new analyses including the investigation of social organisation with regard to harvesting practices and storage. After these analyses, a thorough assessment is provided of the effect of archaeological methodology, taphonomy, and other factors on an botanical assemblage (section 6.4.8). By elucidating such factors, and keeping this in mind during interpretation, the results of this chapter yielded a clearer image of past human selection and practice.

6.4.1 Arable fields and crops

Arable fields

Throughout West Frisia, evidence for ploughing in the form of *ard* marks were uncovered. Although providing rare and valuable information on the practice of ploughing in the Bronze Age (section 6.4.2), these marks cannot be directly translated into arable field size. The first aspect that makes the interpretation of field size difficult is that ard marks are not always continuous, and usually not present over longer distances. This is due to the fact that ards only pierce the subsoil in certain instances, and the the original length of the ploughed furrow is often lost, only becoming visible during excavation as a discontinuous feature (section 6.3.1). Although discontinuous, these features do show a similar orientation, which means that their continuity may still be postulated based on this observation (see below). The second aspect that encumbers the analysis of field size based on ard marks is that clear boundaries of arable fields are not always found or recognised, or may even have been absent in the past as well. In West Frisia, also no clearly bordered arable fields were uncovered and it was therefore only possible to determine a potential minimum field size based on the ard marks themselves.

West Frisian ard marks

The most meticulously excavated site with regard to ard marks in West Frisia, Hoogkarspel Tolhuis: find spot F, was employed to create a general overview of arable field size, ploughing practices, and length of field use (cf. Roessingh in prep.). Minimal arable field size was estimated by measuring the size of the spread of ard marks with similar orientation. Ard mark orientation was portrayed by assuming perpendicular ploughing and this orientation was used to find matching ard marks throughout the settlement. Each orientation was indicated by a different colour. The simultaneous occurrence of different colours/orientations at the same locations were interpreted as multiple phases of use.

Other sites with ard marks were compared with Hoogkarspel Tolhuis to draw conclusions for West Frisia in general.

Ard marks at Hoogkarspel Tolhuis, find spot F

An overview of the existing ard marks in Hoogkarspel Tolhuis find spot F, and their orientations, can be seen in Figure 6.10. What is apparent from Figure 6.10a is that there seems to be a differentiation between and within the north and south half of the excavation with regard to the orientation of the ard marks. Each of the different colours of ard marks observed in Figure 6.10a presumably indicates a different use phase in which the orientation of ploughing is slightly different to the previous year. Orientations which are not observed at other locations may indicate a different arable field altogether (Roessingh in prep.). In this manner, five of such orientation differences were recognised by Roessingh in an attempt to identify different fields present at Hoogkarspel Tolhuis find spot F (Figure 6.10a). The sizes of these arable fields are as large as 75 x 75m.

Several of the most densely marked areas of the excavation were examined in more detail (*e.g.* Figure 6.10b). Almost every area with ard marks

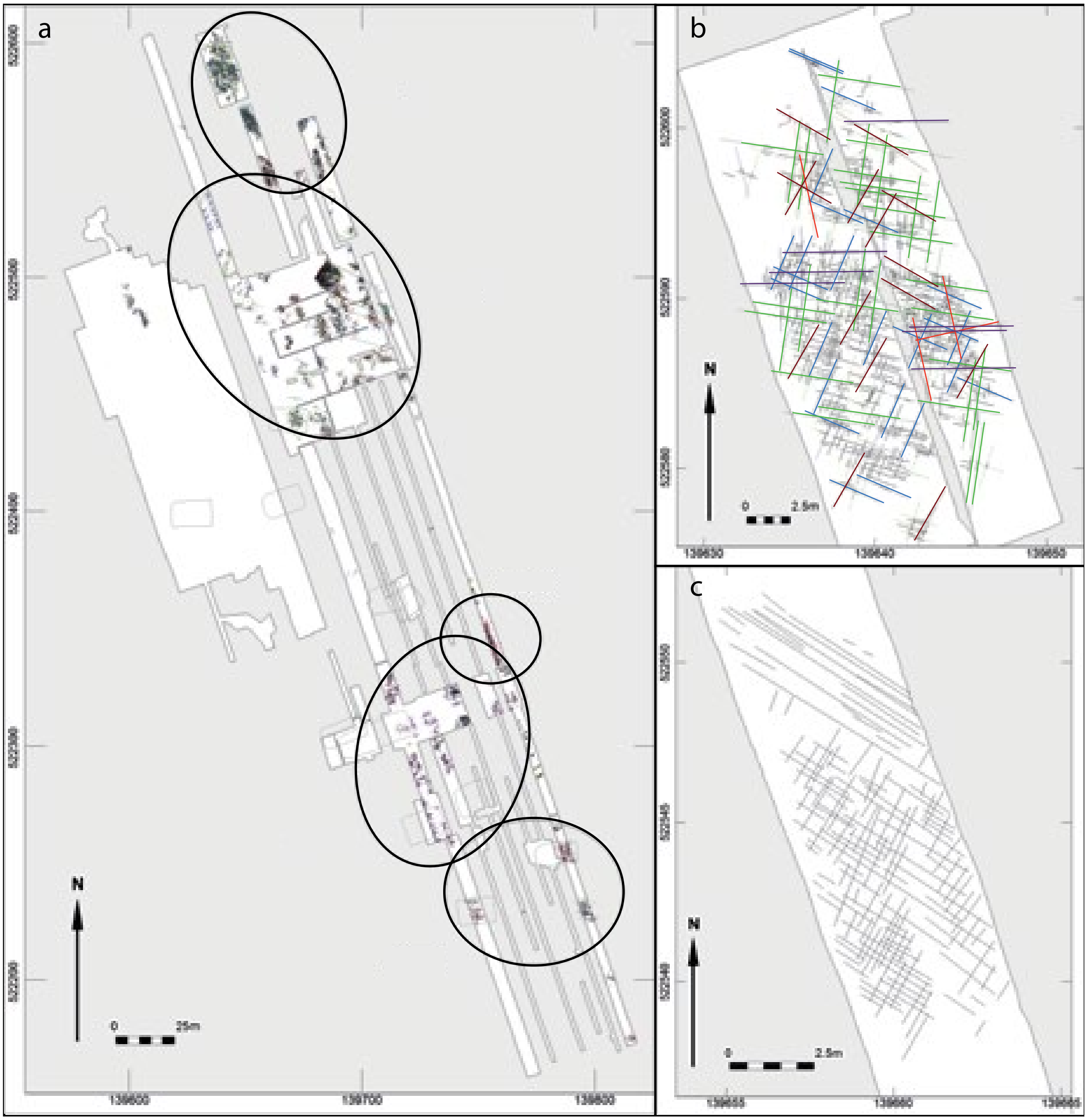

Figure 6.10. Ard marks from Hoogkarspel Tolhuis F; a: overview of the ard marks and their orientations; circles denote possible arable fields (cf. Roessingh in prep); b: detail of the different orientations of ard marks (centre); c: an example of a possible field boundary can be observed, which was similar to Bronze Age field boundaries from Denmark (cf. Figure 6.5).

showed multiple orientations, indicating that arable fields were used for more than one phase, and up to six phases (Figure 6.10b). How long each use phase lasted is unknown, but in general, the ard marks could be relatively dated based on other features to the Early Middle, Middle, and Late Bronze Age (pers. comm. W. Roessingh), indicating the use of the same arable fields over long periods of time.

No clear boundaries of arable fields have (yet) been established, but several examples of possible boundaries do exist. Comparisons with field boundaries in Denmark (*i.e.* parallel ploughing) were found at several locations in Hoogkarspel (*e.g.* Figure 6.10c). Possible boundaries did not occur on all sides, which meant that the exact size of the arable fields could not be measured, but as already mentioned, the minimal field size based on the ard marks was around 75 x 75 m. This minimal field size translates to around 0.6 ha and is slightly larger than the observed field sizes based on ethnographical parallels, but it does concur with the expected size of Bronze Age arable fields based on expected nutritional requirements (cf. Fokkens 1991, 157; Bakels & Zeiler 2005; section 6.3.1).

However, 0.6 ha is hardly enough to sustain one family, let alone an entire settlement, so it must be concluded that more and possibly larger fields must have been present around the settlement, such as was observed at Noorderboekert, West Frisia (section 6.3.1).

Crops

Crop composition

The botanical remains from the West Frisian (WF) sites (including Bovenkarspel Het Valkje, Enkhuizen, Hoogkarspel Tolhuis, Hoogkarspel Watertoren, Hoogwoud, Westwoud, Medemblik Schepenwijk II, and Twisk) were compared with the data presented by Stika and Heiss for the Bronze Age in Europe (Stika & Heiss 2013; Table 6.4). Similar to their research, the West Frisian botanical remains derived from all the different kinds of settlement contexts, and included all states of preservation. Unfortunately, no botanical remains of the EBA were analysed in West Frisia so far. Therefore, only the MBA and LBA remains are available for comparison. The results are summarized in Table 6.5. Mainly emmer and barley are discussed in this part of the research (Appendix A1.9), since the other crops were most likely of secondary importance to the food economy. These other crops, including broomcorn millet (*Panicum miliaceum*) and linseed/flax (*Linum usitatissimum*) (Appendix A1.9), are only shortly discussed where appropriate in the main text, but their importance to subsistence in other ways, and the reasons why they are most likely not contributing much to the food economy are discussed in more detail in sections 6.4.8.2 and 6.4.8.4.

Bronze Age

When comparing West Frisia with the other regions, several things stand out. First of all, throughout the two periods, emmer seems to be just as dominant or even more dominant than barley in West Frisia, whereas in other regions, barley is the dominant crop. Since these crops are most frequently and constantly identified, the main focus of the crop husbandry practices in subsequent sections is on these cereals. Other crops are shortly discussed in the various sections in 6.4.8.

Middle Bronze Age

In the Middle Bronze Age, most cereal crops, except emmer, follow the pattern of southern Scandinavia and the North Sea coastal sites. However, in West Frisia, linseed appears to be more frequent, and one charred flower base of cultivated oat was found in Medemblik Schepenwijk (Schurmans 2010, 227). In addition, several records of wild oat (*Avena fatua*) were made in Bovenkarspel Het Valkje and Westwoud (Buurman unpublished data; Buurman 1996, 118-9) and remains of oat species in general (*Avena* spec.) were frequent, also in house ditches, which may be related to its other use: fodder (see section 6.4.8.4). Pulses were, as expected, mainly absent from West Frisia in the Middle Bronze Age, which is comparable to the Southern Scandinavian and North Sea Coastal situation. Still, remains of vetch (*Vicia* spec.) were frequent, especially in house ditches. Finally, the presence of linseed/flax was higher in West Frisia than in both of the other regions. Broomcorn millet was also found, but in low frequencies at both Bovenkarspel Het Valkje and Hoogkarspel Watertoren.

Table 6.5. Comparison of West Frisian cultivated plants compared with the neighbouring regions in Europe.

		MBA			LBA		
Taxa	**English name**	**SSc and NSC**	**WCE**	**WF**	**SSc and NSC**	**WCE**	**WF**
Cereals							
Hordeum vulgare	Barley	+++	+++	+++	+++	++	++(+)
var. *vulgare*	Hulled barley	+	+	+	+		+
var. *nudum*	Naked barley	+	+/-	+/-	+		+/-
Triticum dicoccum	Emmer wheat	++	++	+++	++	++	+++
Panicum miliaceum	Broomcorn millet	+/-	+	+/-	+/-	++	+/-
Avena sativa	Oat	-	-	+/-	+/-	+	-
Pulses and Legumes							
Vicia sativa	Common vetch	-	-	+/-	-	+/-	-
Oil-containing Plants							
Linum usitatissimum	Linseed/ Flax	+/-	-	+	+	+/-	+/-
*Brassica rapa**	Field mustard	?	?	+/-	?	?	+/-

In this table, only species that have been found in West Frisia are mentioned. The species that were not found here, but were in the other areas, can be observed in Table 6.4 instead. *Although field mustard (*Brassica rapa*) is included in the table as a potential oil-containing plant, as it has been cultivated for this property from Roman times onwards (Weeda *et al.* 1987, 46), many varieties of these plant exist that are only exploited for their vegetative parts. Therefore, for the Bronze Age it is considered to have been collected for this latter purpose (see Chapter 8). +++=dominance, ++=subdominance, +=present, +/-=low amounts, -=absent (adapted from: Stika and Heiss 2013, 358-9).

Late Bronze Age
The West Frisian Late Bronze Age is characterized by the presence of very few cultivated crops. Only barley and especially emmer were found, with minor evidence for broomcorn millet, linseed, and narrow-leaved common vetch. In this respect, West Frisia still resembles Southern Scandinavia (SSc) and the North Sea coast (NSC) the closest, although here, at least some records of other cereals and the oil-containing crop gold-of pleasure were made. A reason for the low amount of crop plant species in West Frisia could be that the Late Bronze Age contexts are far less prevalent than those from the Middle Bronze Age (n=173 and n=23, respectively) decreasing the chance of finding the more obscure plant species which were uncovered in the other regions. Field mustard (*Brassica rapa*), of which varieties have been cultivated for their oil since Roman times (Weeda *et al.* 1987, 46), was uncovered at comparable frequencies to linseed/flax. However, in this research, this plant is considered to be collected for its vegetative parts (*i.e.* wild turnip variety) during the Bronze Age (cf. Chapter 7, section 7.4.2).

Broomcorn millet and linseed/flax, which were also present in the Middle Bronze Age, seem to be stable or decreasing in frequency, although this latter observation may be related to the fewer amount of samples available for the Late Bronze Age.

Overall, West Frisia seems to resemble the southern Scandinavian and North Sea coastal sites the closest. The focus lies on cereal crops, with a clear dominance of emmer over barley, whereas pulses and oil-containing crops only occur in low frequencies throughout the Bronze Age. The reason for a dominance of emmer wheat might be related to environmental conditions, human preference or selection, or yield/ha. Environmental conditions are however not likely to have influenced the shift to emmer, since the conditions of the arable fields remains largely the same throughout the Bronze Age (section 6.4.5). The marked presence of wild oat, and several types of vetch (*i.e. Vicia* spec., *Vicia hirsuta*, *Vicia sativa* ssp. *angustifolia*) might point towards the exploitation of these types of wild plants rather than cultivating pulses and oil-containing plants on the settlement (see Chapter 7, section 7.4.2.1 and 7.4.5).

Intensive vs. extensive and gardens vs. fields
In West Frisia, no definite boundaries of settlements have been identified. This indicates that not many clear off-site situations have been excavated, which hinders the analysis of how intensive crop cultivation was. It is, for example, unclear exactly how far arable fields were situated from the houses; it is hard to assess whether ard marks and other features are contemporaneous due to a lack of overlapping features (section 6.4.5). At the Early Bronze Age site of Enkhuizen Rikkert, however, a large area of ard marks was uncovered without clear indications of habitation. This observation shows that at least during this time, fields were situated further away from the houses. Based on this single example it is hard to assess the intensiveness of crop husbandry. However, the close proximity of Middle Bronze Age settlement sites (Figure 6.1) does indicate that at least during this period, fields could not have been situated too far from the settlements, which is more compatible with intensive crop husbandry practices. Still, it was not possible to evaluate the level of intensiveness of crop husbandry practices during this period or the Late Bronze Age based on features and relative distances. The absence of only annual crop weeds in both periods (section 6.4.2) does however indicate that intensive crop cultivation was occurring in the (later) Bronze Age throughout West Frisia.

Besides the presence of borders, the presence of garden cultivation could also not be established. The absence of indications for garden cultivation might very well be related to the fact that if gardens were cultivated, it was most likely done by hand (*e.g.* with a hoe; section 6.3.1), which often leaves no recognisable features in the soil. Since hand tools usually protrude less deep into the ground than a plough, evidence for their use may only be uncovered by micro-morphological analysis (Huisman & Raemaekers 2014). Another reason why gardens are difficult to recognise is the fact that in these plots, often other types of crops are cultivated such as root crops and vegetables (section 6.3.1), which are also almost never found archaeologically. Therefore, it could not be assessed whether gardens were cultivated in West Frisia.

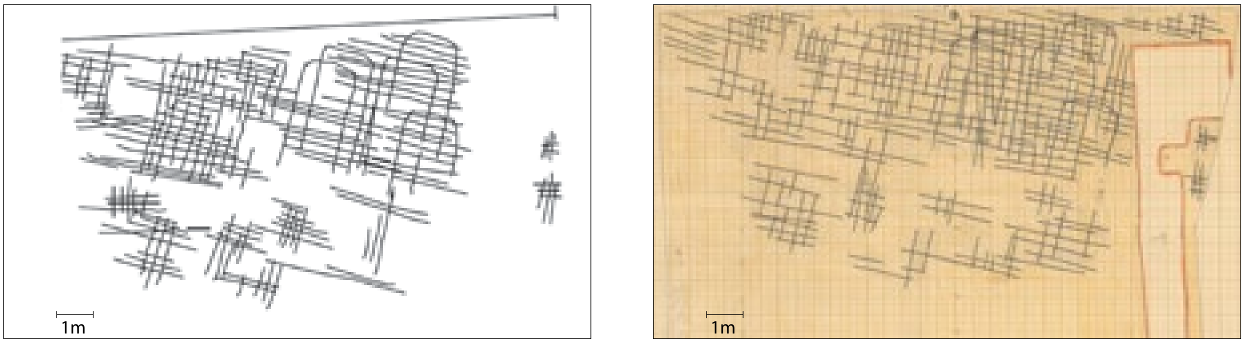

Figure 6.11. Examples of features interpreted as possible turning points uncovered at Bovenkarspel Het Monument. The turning radius observed however, is too small for cattle with plough (Appendix A1.10). a: digitalized image of the plough marks at Bovenkarspel Het Monument; b: scan of the original field drawing of the the plough marks at Bovenkarspel Het Monument.

6.4.2 Soil preparation

Ploughing

The presence of ard marks from different phases throughout the Bronze Age at almost every site indicates that ploughing occurred regularly in West Frisia.

A possible interesting insight into past ploughing practices was observed at the excavation Bovenkarspel Het Monument (Roessingh in prep.). Here, five possible marks of the turning point of an ard were excavated, indicating that a pair of cattle and the plough may have turned at this point to continue ploughing in the opposite direction (Figure 6.11a). In order to assess whether indeed these features could be related to the turning of a cattle pair and ard, the turning radius of such a configuration was calculated (Appendix A1.10). Under the assumption that the cattle pair turned with the plough remaining in the soil during the turn, which would results in a continuous feature as observed in Figure 6.11a, the minimal turning radius of cattle pair and plough would be ca. 3.5-5.0 m (Appendix A1.10). This radius is of comparable relative size to radii observed with larger traction animals (ca. 5.0-7.0 m: Lerche 1986, 139-142). The calculated turning radius of a cattle pair and plough is, however, far too wide to match the 0.75 m radius observed in Figure 6.11. Other reasons why the marks observed at Bovenkarspel Het Monument most likely do not represent turning points are that in the original field drawing (Figure 6.11b) the turning point angles are intermixed with continuing vertical plough marks, and additional horizontal marks are visible to the north of the turning points, neither of which would support the hypothesis that the turning points represent the border of an arable field.
Alternative principles of turning a plough are observed in other areas of the world even today, where simple ploughs such as the ard are lifted from the ground at the field border and are again placed into the soil when the turn is completed (Varisco 1982, 167; Lerche & Steensberg 1983, 237; Schjellerup 1986, 185). Such a practice remains invisible in the archaeological record, because the turning process cannot be recorded in the soil. Perhaps this is a more appropriate option for the ploughing practices in Bronze Age West Frisia, at least until other plausible evidence for turning points are observed. The observed features at Bovenkarspel Het Monument remain unclear in their original function, but can for now be ruled out as turning points.

Burning

Burning of arable fields after harvest can be considered a plausible crop husbandry practice in West Frisia. This was established by the analysis of a Bronze Age arable field, which contained a black layer in the soil, which is seen at many West Frisian excavations. The arable field soil was analysed with the aid of pollen analysis, phytolith analysis, and micro-morphological analysis. Both the pollen analysis and the micro-morphological analysis have identified the presence of charcoal particles in the arable field layer. Phytolith analysis has also shown that phytoliths from grasses (Pooideae) were present in the layer, although it could not be established with certainty that those were cereals. However, the fact that the phytoliths were discoloured black in a sample from an arable field indicates that vegetation on the field was burned. Stubble could have been burned, or, alternatively, the vegetation on the arable field may have been burned after a fallow period. Regardless of the type of vegetation burned, arable field burning appears to have been practiced in West Frisian Bronze Age crop husbandry. The extent of this practice and more details regarding the practice will have to become apparent after more (micro-morphological) research has been completed (Pronk in prep.).

Crops in West Frisia were most likely harvested at a maximum height of 40-60 cm (section 6.4.3). For adequate crop stubble burning, at least 3-4 inches (*i.e.* 7-10 cm) of material needs to be left on the field in order to allow for adequate burning (Kansas Forage Task Force 1998). It seems that the height of the stubble in West Frisia would have allowed for stubble burning.

Fallow

The presence of fallow periods is assessed in archaeobotanical assemblages by the presence of perennial crop weeds. Such weeds, as opposed to annual weeds, live for more than one year. When these perennial crop weeds are found amongst the grain on a settlement, it means that they were able to reach maturity and that the arable field where they originated experienced years in which ploughing or weeding did not occur (*i.e.* fallow).

In West Frisia, the crop weeds from every Middle and the Late Bronze Age site were annual weeds (Table 6.6). This implies that (near-)continuous cultivation was occurring during this time. Based on these results, it is highly possible that the method ofcultivation practiced by West Frisian farmers tendered towards Boserup's annual cultivation land use model (Table 6.3). The close proximity of settlements to each other (section 6.4.1) also indicated the probability of more intensive cropping practices than was expected.

6.4.3 Cultivation

Sowing

Spring or autumn sowing?
The sowing season of cereal crops can be reconstructed based on the composition of accompanying crop weeds. Only crop weeds deriving from locations related to arable fields (*i.e.* eco group 1a and 1c[11]; Tamis *et al.* 2004) were used, therefore excluding plants such as fat hen (*Chenopodium album*) and fig-leaved goosefoot (*Chenopodium ficifolium*), which belong to eco group 1e. The results are summarized in Table 6.6 for both the Middle and Late Bronze Age. Enkhuizen Kadijken is only represented by Middle Bronze Age remains.

Middle Bronze Age
The most frequently found weeds are chickweed (*Stellaria media*), black nightshade (*Solanum nigrum*), red leg (*Persicaria maculosa*), barnyard grass (*Echinochloa crus-galli*), field speedwell-type (*Veronica agrestis-type*[12]), and prickly sow thistle (*Sonchus asper*). Chickweed is a summer/winter annual, which would not give consistent indications of time of sowing crops, similar to field speedwell. Black nightshade, red leg, and barnyard grass however, are summer annuals, which grow together with spring-sown crops. The combination of these weeds therefore points towards spring sowing.

Late Bronze Age
In the Late Bronze Age, the assemblage of crop weeds changes very little. The only change visible is a decrease in the number of species in comparison to the Middle Bronze Age. This however, can be attributed to the lower amount of Late Bronze Age samples.

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11. Eco groups reflect the general preferred location at which a plant occurs. The used eco groups here are 1a: arable fields on nutrient-rich, non-calcareous soil; 1c: arable fields on medium nutrient-rich, poor calcareous soil; 1e: brushwood on rarely trodden, nutrient-rich, non-humous or calcareous, dry soils (after: Tamis *et al.* 2004; also see: Chapter 7, Table 7.4).
12. Includes the species field speedwell (*Veronica agrestis*), grey field speedwell (*Veronica polita*), and dark speedwell (*Veronica opaca*) based on morphological characteristics.

Middle Bronze Age				
Taxa	**English name**	**Life cycle**	**Summer/winter crop weed**	**Height range (cm)**
Anagallis arvensis	Scarlet pimpernel	Annual	Inconsistent	5-50
Chenopodium polyspermum	Manyseed goosefoot	Annual	Summer?	10-80
Echinochloa crus-galli	Barnyard grass	Annual	Summer	10-120
Euphorbia peplus	Petty spurge	Annual	Summer?	7-30
Fallopia convolvulus	Black bindweed	Annual	Summer?	100-120
Fumaria officinalis	Fumitory	Annual	Summer?	10-50
Lamium purpureum	Red/Purple deadnettle	Annual	Summer?	10-30
Persicaria maculosa	Red leg	Annual	Summer?	20-100
Silene gallica	Common catchfly	Annual	Summer?	15-50
Solanum nigrum	Black nightshade	Annual	Summer?	5-60
Sonchus asper	Prickly sow thistle	Annual	Summer	30-60
Stellaria media	Chickweed	Annual	Inconsistent	10-40
Urtica urens	Annual nettle	Annual	Summer	15-60
Veronica agrestis-type	Field speedwell	Annual	Summer?	7-30
Veronica hederifolia	Ivy-leaf speedwell	Annual	Summer?	5-30
Veronica persica-type	Birdeye speedwell	Annual	Summer?	15-30
Vicia hirsuta	Hairy tare	Annual	Summer?	15-60
Late Bronze Age				
Echinochloa crus-galli	Barnyard grass	Annual	Summer	10-120
Fallopia convolvulus	Black bindweed	Annual	Summer?	100-120
Persicaria maculosa	Red leg	Annual	Summer?	20-100
Solanum nigrum	Black nightshade	Annual	Summer?	5-60
Sonchus asper	Prickly sow thistle	Annual	Summer	30-60
Stellaria media	Chickweed	Annual	Inconsistent	10-40
Urtica urens	Annual nettle	Annual	Summer	15-60
Veronica agrestis-type	Field speedwell	Annual	Summer?	7-30
Vicia hirsuta	Hairy tare	Annual	Summer?	15-60
Vicia hirsuta/ tetrasperma	Hairy/smooth tare	Annual	Summer?	15-70

Since the crop weed composition is practically the same, spring sowing is also assumed for the Late Bronze Age.

The likelihood of summer crop cultivation, and therefore spring sowing, was also indicated by the presence of cultural landscape-related bird species which prefer this crop variety over winter crops as a habitat for nesting during breeding season (Chapter 2, section 2.4.5.3).

Sowing practices

The reconstruction of actual sowing practices was not possible, since sowing regimes cannot be identified in the archaeological record. Due to the inherent characteristics of smaller seeds such as emmer and barley grains (cf. section 6.3.3) it is assumed that broadcasting was the sowing method used. Seeds would subsequently have been covered with soil by harrowing, for example.

Maslin

Although emmer wheat and hulled barley were often found in comparable frequencies (Table 6.5), it is not assumed that maslin crops were cultivated. The relatively low reaping height of crops (see Harvesting below) indicates that people may have used the straw of crops for different purposes (cf. section 6.3.3). Sorting the straw after harvest will have been a tedious task which is easily avoided by growing different crops on separate fields.

Rotation

Pulses and legumes, which are often used to replenish nutrients in arable fields after cereal cropping, are rare in West Frisia in the Bronze Age, and throughout the North Sea coast and southern Scandinavia (Table 6.5). It was therefore not possible to establish a possible rotation scheme of crops.

On the left: Table 6.6. Crop weed species identified in West Frisian house ditches (MBA and LBA). Summary of remains from the sites Bovenkarspel Het Valkje, Westwoud, Enkhuizen Kadijken, and Medemblik. Crop weed composition was overall comparable at each site.

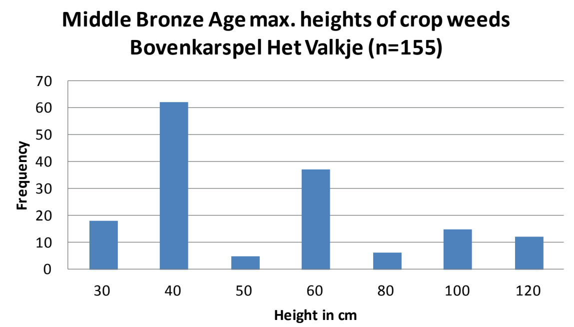

Figure 6.12. Overview of the maximum height of the crop weeds from Bovenkarspel Het Valkje for the Middle Bronze Age; n=155.

Weeding

Several species of crop weed were identified amongst the charred grains in house ditches (Table 6.6).
It can therefore be assumed that weeding was not intense enough to reduce the frequency and species range of the weed species observed.

Harvesting

The height of harvesting can be assessed by the maximum height of accompanying crop weeds. The results of four West Frisian sites are summarized below for both the Middle and Late Bronze Age (cf. Table 6.6).

Middle Bronze Age

The lowest maximum crop weed height identified is 30 cm at nearly every site, followed by a high frequency of crops with a maximum height of 40 cm (Figure 6.12-Figure 6.15). These low maximum heights could point towards harvesting practices where the stems of the crops are cut/removed relatively low, especially considering the low minimum crop weed heights as well (Table 6.6). Harvesting techniques could include reaping low with the use of a sickle or uprooting entire plants. The only high crop weed found (reaching 100-120 cm) is black bindweed (*Fallopia convolvulus*). This is a winding plant, easily collected during the harvest regardless of harvesting technique as it is attached to the cereals.

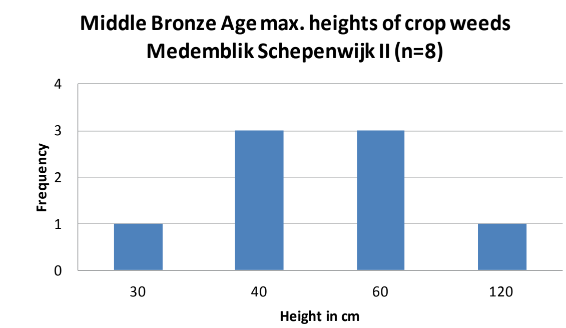

Figure 6.13. Overview of the maximum height of the crop weeds from Medemblik Schepenwijk II for the Middle Bronze Age; n=8.

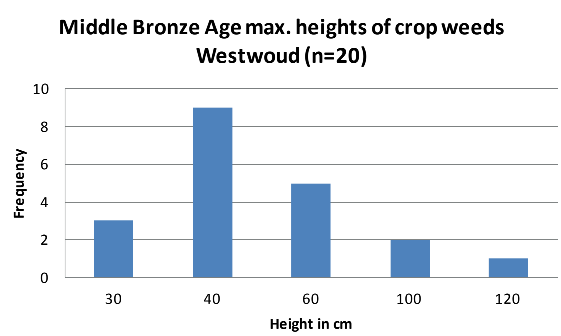

Figure 6.14. Overview of the maximum height of the crop weeds from Westwoud for the Middle Bronze Age; n=20.

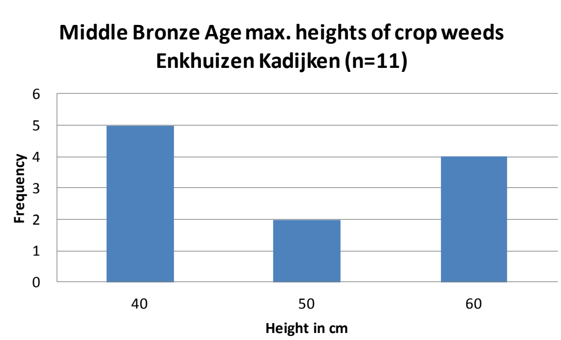

Figure 6.15. Overview of the maximum height of the crop weeds from Enkhuizen Kadijken for the Middle Bronze Age; n=11.

Late Bronze Age

Markedly few botanical remains were found for the Late Bronze Age in comparison with the previous period, so results must be interpreted with care. Also, since Enkhuizen Kadijken yielded no botanical remains from the Late Bronze Age, it is not discussed here. Nonetheless, the results for the Late Bronze Age are summarized in Figure 6.16-Figure 6.18.

Although there are far fewer remains, it seems that the lowest maximum crop weed height of 30 cm is still observed in Bovenkarspel Het Valkje, followed by a high frequency of remains of crop with a maximum height of 40-60 cm and low minimum growth heights, which all still point towards harvesting practices including either low reaping or uprooting.

Reaping or uprooting?

In Westwoud, many charred culm bases were found, with roots still attached (Buurman 1996, 127-8). Although impossible to identify to species level, the concurrence of these large grass culm bases with cereal culm nodes and harvesting waste indicates that they most likely belong to cereal crops. Reeds were excluded as a possible source of the culm bases due to the absence of their indicative creeping rhizomes. These remains derived from later Bronze Age ditch contexts, dating to roughly 1200-900 BC (Buurman 1996, 113). The presence of these culm bases may provide evidence for uprooting practices. However, since many non-winding, free-standing species of crop weed were also found (Table 6.6), reaping low on the culm remains an equally plausible possibility. Still, regardless of the harvesting method, the low reaping or uprooting practice indicates the importance of the culm for other purposes such as bedding, thatching, or basketry (see section 6.4.8.4).

Manner of harvesting

Reaping of culms usually occurs with the use of sickles. However, although remains of flint sickles have been found in West Frisia, use-wear analysis has indicated that these were not used to harvest cereals (van Gijn 2010). In Denmark, similar sickles have been used for harvesting (van Gijn *et al.* 2014, 314). Besides flint sickles, bronze sickles may also have been used for harvesting, but these are rare, and only one example is known from West Frisia (van

Gijn *et al.* 2014, 315). Still, the absence of evidence for harvesting tools does not imply that they were not used/present, and the general scarcity of for example bronze finds exemplifies that many practices cannot be reconstructed based on objects in West Frisia.

Harvest yield, loss, and crop yield factor

It is not possible to accurately reconstruct the yields and losses of prehistoric crops. Therefore, the average yields and losses based on the ethnographic parallels (section 6.3.3) are assumed for West Frisia. This means an average yield of 1.7 t/ha for emmer wheat and 1.2 t/ha for hulled barley, translating to roughly 2,400 kg of emmer wheat or 1,600 kg of barley per household after detraction of 20% losses, and an assumed arable field size of 1.8 ha (cf. section 6.3.1). The crop yield factor is similarly impossible to calculate, so it is assumed that it was comparable to the 1:8 ratio observed in parallel small-scale farming communities.

6.4.4 Crop processing and storage

Post-harvest crop processing in West Frisia

The method of Stevens (Fuller *et al.* 2014) was applied to the West Frisian data to investigate the post-harvest crop processing practices in West Frisia (cf. section 6.3.4). Similar to the selections made by Stevens, a sample was only included in the analysis when it contained sufficient numbers of cereal grains (*i.e.* N > 30) and weed seeds (*i.e.* N > 20). Seeds were considered small when their dimensions were smaller than the width of a cereal grain (*i.e.* 2.5 mm). Seeds were considered large when their size exceeded 2.5 mm, or when they contained characteristics such as appearing in seed heads, possessing appendages, or any other characteristic which increased the likelihood of retention with the grain during sieving. All seed measurements were obtained from the Online Seed Database (Plantatlas 2016) and additional characteristic information from Stevens (pers. comm.). Ratios of large and small weed seeds, as well as total grain to weed seeds were calculated, and the results are shown in Figure 6.19. In this figure, all the data from all the contexts of the sites was included for both the MBA and LBA combined.

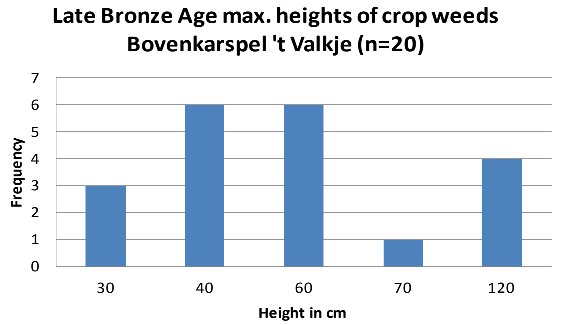

Figure 6.16. Overview of the maximum height of the crop weeds from Bovenkarspel Het Valkje for the Late Bronze Age; n=20.

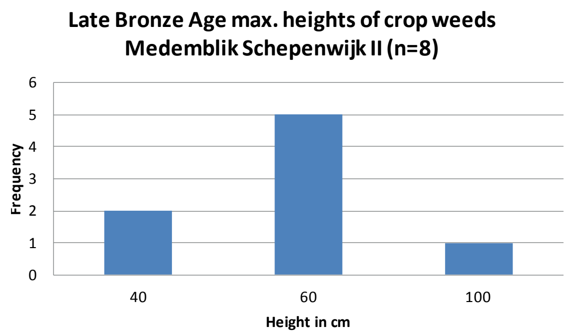

Figure 6.17. Overview of the maximum height of the crop weeds from Medemblik Schepenwijk II for the Late Bronze Age; n=8.

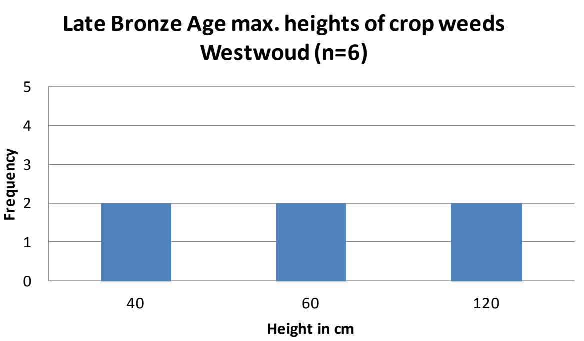

Figure 6.18. Overview of the maximum height of the crop weeds from Westwoud for the Late Bronze Age; n=6.

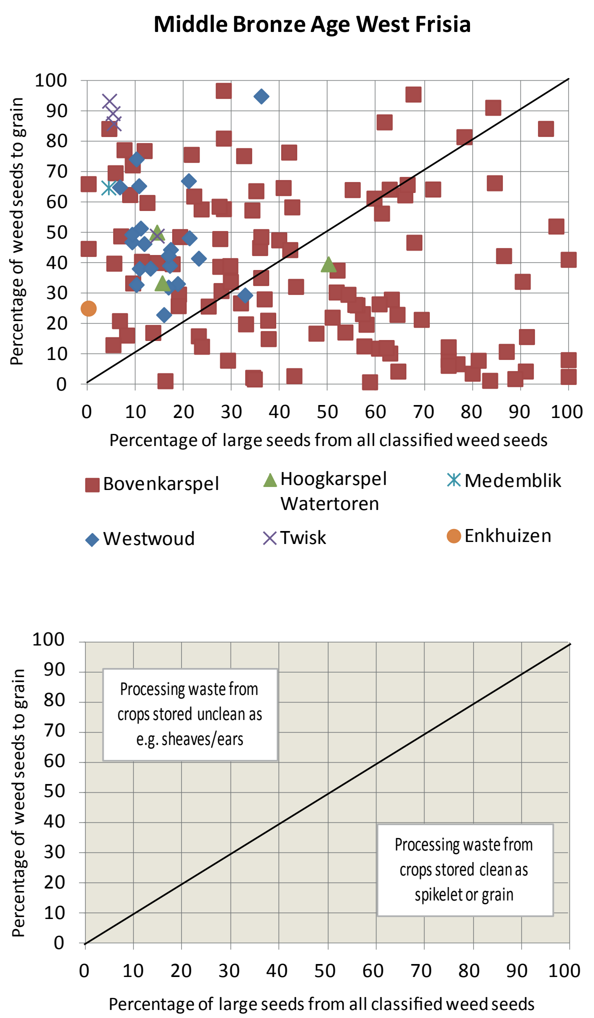

Figure 6.19. Post-harvest crop processing characteristics of all contexts from six West Frisian sites of the Middle and Late Bronze Age combined (above), and interpretative graph of Stevens (cf. Figure 6.8) for comparison (below).

What this graph of the Bronze Age in general shows is that at most of the West Frisian sites, the households can be categorised as small households (data left of the 45 degree angle line). Although most sites did not contain a large number of appropriate samples for the analysis, this small household level organisation trend seems to imply that most sites reflect settlements with houses with few inhabitants. Bovenkarspel Het Valkje however, is an exception which seems to possess both small and large household level organisations for crop

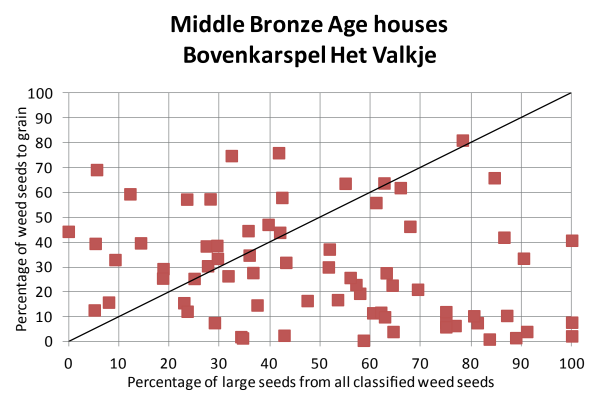

Figure 6.20. Spread of the Middle Bronze Age house data from Bovenkarspel Het Valkje. Clearly, both small and large households seem to be present during this time

processing. Therefore, it was investigated whether the differences observed in Bovenkarspel Het Valkje could be explained by differences between individual households, the location of houses at the settlement, and perhaps even time period.

Post-harvest crop processing in Bovenkarspel Het Valkje

Bovenkarspel Het Valkje has yielded many data which allowed for an in-depth comparison of crop processing characteristics. Since it is assumed that crop processing occurred in and around the house, only house contexts, in this case house ditches, were used to assess differences. The samples from house ditches were used to investigate the Middle Bronze Age situation, and the samples from ditches for the Late Bronze Age situation.

Middle Bronze Age

The data from the Middle Bronze Age houses was summarized in Figure 6.20. Of the total number of identified MBA house plans (Roessingh in prep.), only 24 were selected for analysis based on the richness of their samples. The overall spread of MBA data seems to indicate that during the Middle Bronze Age, both small and large households were present at Bovenkarspel Het Valkje.

In order to gain insight into the characteristics of the individual houses, it was assessed whether the data of each house reflected small households (samples left

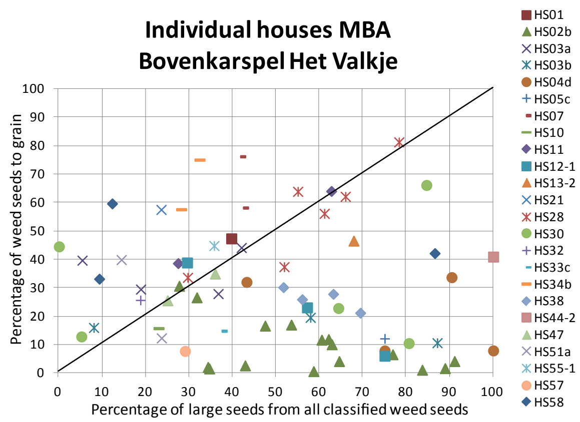

Figure 6.21. The Middle Bronze Age house data from Bovenkarspel Het Valkje, subdivided into individual households to investigate the level of organisation (small household, mixed, or large household). For every house, all the analysed samples are depicted with the same symbol.

of 45 degree angle line), a mixed situation (samples either all on the line or clearly on both sides of the line), or large household level organisation (samples on the right side of the line). In Figure 6.21 all the house ditch samples of the individual houses from Bovenkarspel Het Valkje are plotted, and in Figure 6.22 these houses are designated as either small or large households or a mixed situation. It was not possible to safely place the mixed samples in either the small or large household categories. Therefore, these houses were excluded from further analysis.

Four houses were identified as consisting of small households (House 03a, 07, 21, and 34b), and eight houses as large households (House 02b, 04d, 05c, 12-1, 13-2, 38, 44-2, and 57). Of these small and large household houses, plots were made on the excavation plan of Bovenkarspel Het Valkje to assess whether the location on the settlement could provide further explanations for the differences observed (Figure 6.23 and Figure 6.24).

Clearly, both small and large households are dispersed over the settlement, which does not provide clear indications for a spatial differentiation of separate areas with different practices. Interestingly however, a possible temporal difference was observed, since the four small households are all either first phase houses or single phase houses located separate from

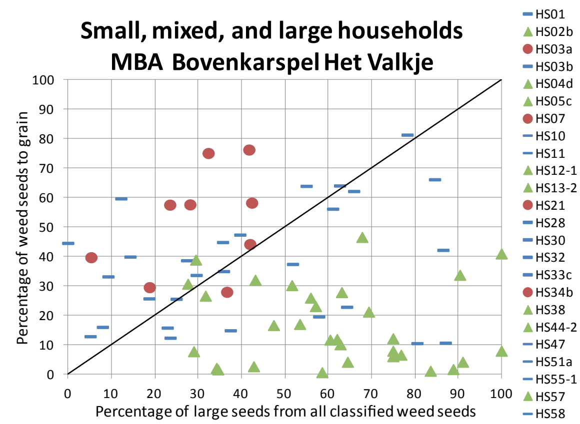

Figure 6.22. Translation of the Middle Bronze Age house data from Bovenkarspel Het Valkje from Figure 6.21, showing the level of organization per household. Houses of which samples are generally left of the 45 degree line are considered small, houses samples generally right of the 45 degree line are considered large, and all households showing ambiguous samples are considered mixed.

other features (Roessingh in prep.). This observation implies that perhaps the different levels of crop processing organisation might also reflect settlement changes through time. Suppose that the four small households are the first houses of the settlement Bovenkarspel Het Valkje. Not many people and therefore hands would have been available to harvest the fields, resulting in small household level organisation of post-harvest crop processing. As the Middle Bronze Age progresses, more houses and people inhabit the settlement, gradually increasing the number of inhabitants of houses to include large households. Indeed, in two instances it was possible to assess the stratigraphy of the houses, and house 3a (small household) shifts to a mixed situation in the next phase, house 3b, indicating a movement towards larger households. A similar shift is observed in house 10 (mixed) towards the next phase of the house, house 12-1 (large household). In all the instances in which stratigraphy could be assesses, there is never a movement in the opposite direction (from large to small household level) visible for the Middle Bronze Age.

Late Bronze Age

Both Middle and Late Bronze Age data are summarized in Figure 6.25. The Late Bronze Age samples derive from deep Late Bronze Age ditches,

Figure 6.23. Plot of the small households (red dots) on the excavation plan of Bovenkarspel Het Valkje.

which are assumed to be comparable to the Middle Bronze Age house ditches.

Where in the Middle Bronze Age both small and large households appear, the Late Bronze Age samples seem to almost solely reflect small household level organisations: a change in post-harvest crop processing organisation seems to be occurring, where, similar to the four small households in the Middle Bronze Age, again fewer people or less time are available for harvest processing.

A possible reason for the observed change in practice in the Late Bronze Age might be explained by the increasing wetness in the environment (Chapter 2). The resulting shortage of land would mean that less people could have sustained themselves in West Frisia during this time (Chapter 8). In turn, the decrease in available hands may have resulted in a relapse into small household level organisation of crop-processing, similar to the four houses in the Middle Bronze Age.

Possible other explanations for the differences observed

Many other forms of social organisation may also have existed. Households may for example have worked together during harvest and harvest processing, similar to what is observed in the ethnographic parallels (section 6.3.3). However, there is no time advantage to this practice when only small households participate that also have to complete their own harvest. This

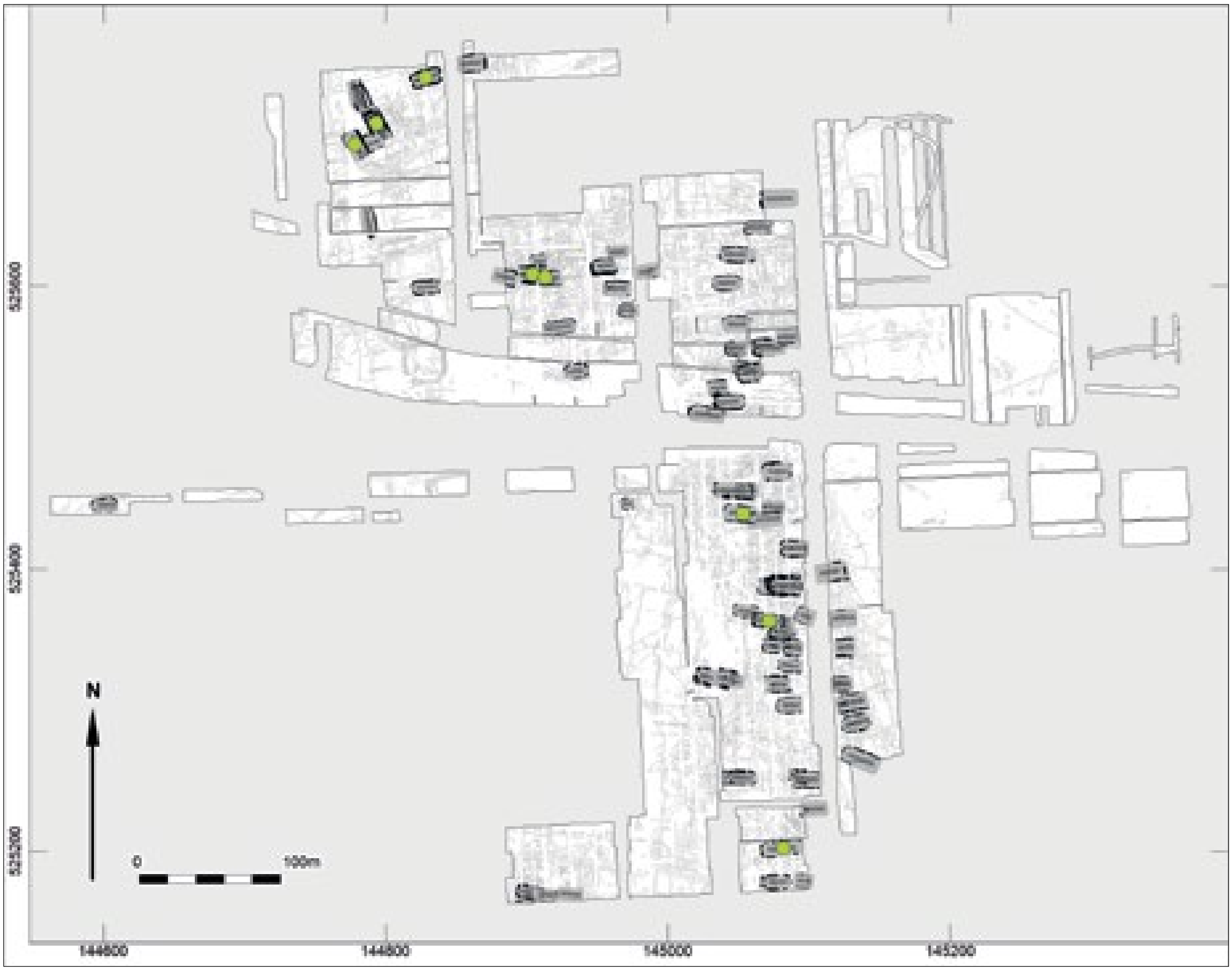

Figure 6.24. Plot of the large households (green dots) on the excavation plan of Bovenkarspel Het Valkje

means that even if small households work together, they would not be able to reflect the practices of large households. Therefore, collaboration between small households in this manner will in the larger picture not be distinguishable from normal individual small household practices.

An alternative possible explanation for the difference in household size may be the result of the combination of two types of storage within one settlement (pers. comm. Stevens); each (small) household may have its own unclean store of grain, whereas a larger communal clean store of grain may also be present. It is possible that such practices explain the presence of mixed households or buildings with an entirely different function, as observed in Chapter 8 (section 8.5).

Storage

Possible storage locations in West Frisia are not so clear compared to other, contemporaneous areas in the Netherlands. At these locations, storage is assumed to have been in granaries or silos which are separate from the main house. In West Frisia however, no such types of storage structures have been found. The only configuration of features which has been connected to the storage of cereals is the ring or post hole ditch (Figure 6.26) based on the presence of charred grain in one of the post holes of one post hole ditch (Buurman 1996, 205). However, in none of the other excavated ring or post hole ditches have any remains been found that would concur with the conclusions drawn previously by Buurman. Therefore, until further evidence is found

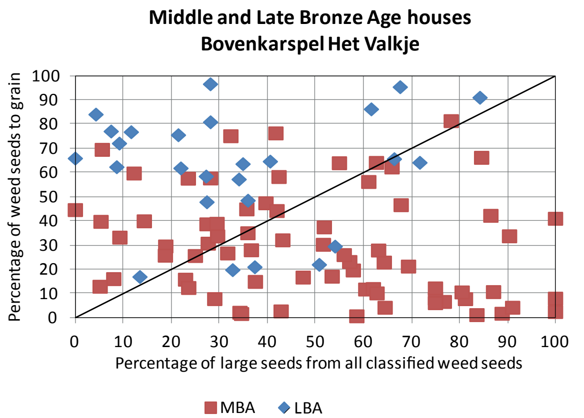

Figure 6.25. Spread of the Middle and Late Bronze Age house data from Bovenkarspel Het Valkje. Clearly, Late Bronze Age houses cluster more in the small households category.

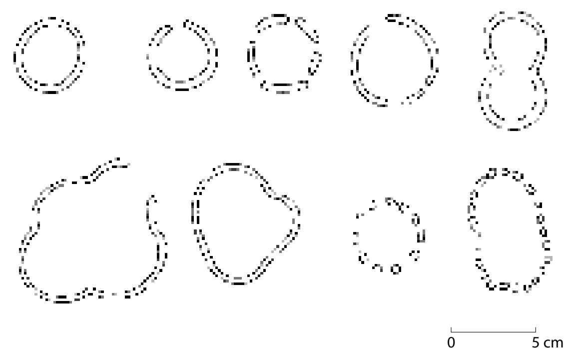

Figure 6.26. Examples of ring and post hole ditches that are postulated to be connected to the storage of cereals grains (after: Buurman 1996, 205).

for the function of these features, they are not assumed to be connected to the storage of harvested cereals and will not be discussed any further in this thesis.

Without a clearly defined structure for cereal grain storage present at the West Frisian settlements, the grain may have been stored in the attic of the house (cf. section 6.3.4). The average house in West Frisia possesses around 45 m^3 of attic space (Appendix A1.12). Since grain should not be kept over possible barn areas, and the living quarters are hypothesized in the western part of the house (cf. section 6.3.4), the available appropriate attic storage space in West Frisia will most likely be 22.5 m^3 or less, depending on the size of the barn area. The expected 4 m^3 of space required for the storage of an average annual harvest in spikelet form is easily accommodated by this space; even storage in ears or sheaves, presumed for smaller households, would be possible. The remaining space could be used to store possible other goods such as dried or salted meat or fish (Chapter 4, section 4.4; Chapter 5, section 5.4), and fodder (Chapter 5, section 5.4).

6.4.5 Improvement and location of arable fields

Soil conditions

The growing conditions of crops on arable fields were analysed using the Ellenberg values (Ellenberg *et al.* 1991) of the crop weeds from four sites: Bovenkarspel Het Valkje, Enkhuizen, Medemblik, and Westwoud. These values of crop weeds provide information on abiotic environmental factors such as salinity, moisture, pH levels, and nitrogen levels, the results of which are shown below for both the Middle and Late Bronze Age (Figure 6.27-Figure 6.30).

Salinity

Figure 6.27 shows the average salinity tolerance of the crop weeds from West Frisian arable fields. It becomes clear that both in the Middle and Late Bronze Age, fields were under fresh water conditions, since all crop weeds are intolerant of even low levels of salinity.

Moisture

West Frisia is known for its increasing wetness throughout the Bronze Age. The arable fields however, as can be seen in Figure 6.28, were situated at such locations, that at least during the growth period of the plant, no excessive moisture was present on the arable field. The moisture levels vary through time, but do not show a definitive trend towards higher moisture content in the Late Bronze Age. The range of moisture portrayed by the crop weeds reflects ideal circumstances for cereal growth. In addition, no indicators for flooding were found (data not shown).

pH value

The pH of the soil of the arable fields was very favourable (Figure 6.29). Most plants reflect a pH of 7.0, which is neutral and very good for plant growth.

There is no clear change between the Middle and the Late Bronze Age.

Nitrogen
The results from the nitrogen level of crop weeds (Figure 6.30) shows that nutrient conditions on the arable fields were very high, although some lesser values are observed in the Late Bronze Age. Such high nitrogen levels are often related to the practice of manuring, which is further discussed next.

Manuring

Manuring was not expected to have been practiced, but a recent nitrogen isotope experiment has shown that artificially heightened nitrogen levels did exist in the West Frisian soils (Appendix A1.11).

Although the exact source of nitrogen cannot be established based on such an analysis, it is clear that some form of fertilizer has been applied to the arable fields. Possible types of fertilizer include household waste, green manure (nitrogenous plant material), and animal manure (*i.e.* animal dung mixed with straw etc.).

Since it is assumed that West Frisian farms were mixed farms, the potential use of animal manure is likely. However, some factors need to be taken into consideration before a definite conclusion can be drawn. First, how much manure was actually available per farm? Second, how much manure is minimally required to fertilize the arable fields? And third, is the application of animal manure a probable option for West Frisia?

In order to answer the first question, it is necessary to make several assumptions. It is assumed that the main manure suppliers in the West Frisian Bronze Age were small cattle, sheep/goat, and pig. Parts of the cattle and sheep/goat herd (valuable and vulnerable animals) were kept inside during winter months (cf. Chapter 5, section 5.4.3), providing manure from roughly November to February. Pig manure could be used year-round, since pigs would probably have been kept in a delimited area within the settlement (Chapter 5, section 5.3.4).

The manure production of Dexter cattle, which is of comparable size to Bronze Age cattle, lies around 15 litres of solid manure on a daily basis (pers. comm. A. Slagter, Dexter cattle breeder). This amounts to around 1.83 m^3 when it is assumed that cattle was kept inside for four winter months (*i.e.* 122 days). Pigs produce on average 4.6 m^3/yr of manure (Alberta 2013, 43-4). If we assume that on a settlement of two houses, two pigs were kept year-round, as well as five adult cattle were stalled inside in winter, the total amount of manure available for a settlement (including pig and cattle manure) would be 18.4 m^3.
In order to calculate the amount of necessary manure to fertilize the arable fields, the example of Sukumaland, Tanzania was used (section 6.3). Farmers in Tanzania possess small-scale mixed farms on mostly clayey soils and need to transport 7.5-20 t/ha of manure to fertilize fields (Meertens *et al.* 1995, 78; Carton & Magette 1999). This amounts to 21-57 m^3 of manure per hectare.

The Bronze Age settlement, consisting in this example of two contemporaneous houses, possesses in total 3.6 ha of arable fields. Using the example values of Tanzania, these fields would therefore require a total of 42-114 m^3 of manure to fertilize. It is clear that there is a considerable imbalance between manure supply and demand, similar to what was observed in Asturias, Spain (section 6.3.5). Either cattle was not just kept inside during winter, allowing for enough manure to be produced, manure was collected in a different manner, or manuring with animal dung was not practiced on a large scale in West Frisia.

Alternatively, if all cattle was kept inside year-round or manure was collected in some other way, a total of 57 m^3 of manure (7 adults and 2 immature animals, producing full amounts of manure, and 3 young, producing half) could have been produced and collected. Together with the pig manure, this would have been enough to fertilize all fields. However, the amount of labour which needs to be employed in foddering animals year-round versus letting them graze, as well as the effort of transporting all the manure to the arable fields would not have been a feasible practice for such small settlements.

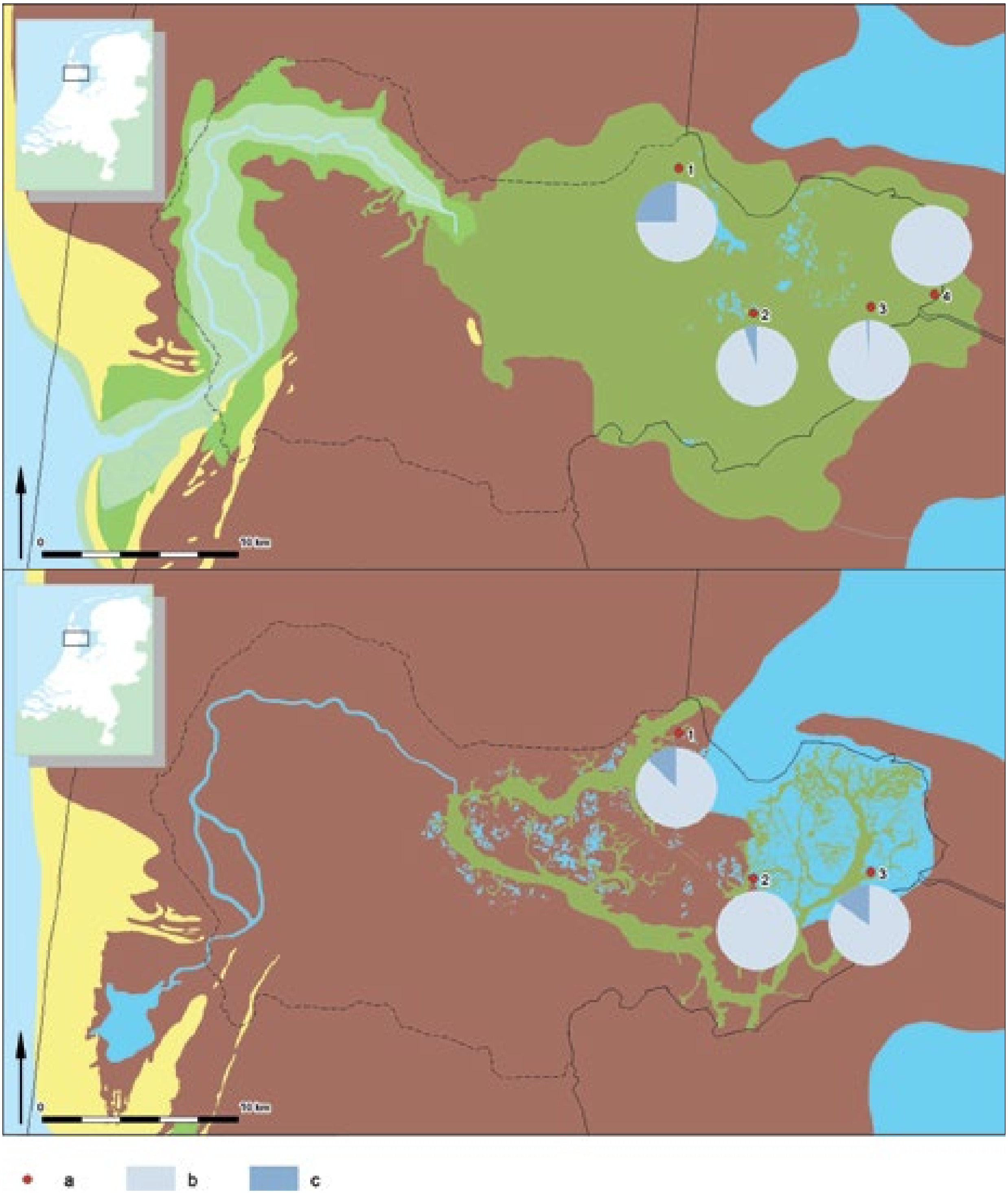

Figure 6.27. Soil salinity tolerance levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: does not tolerate salt (*i.e.* fresh water); c: extremely low salt toleration (*i.e.* fresh water).

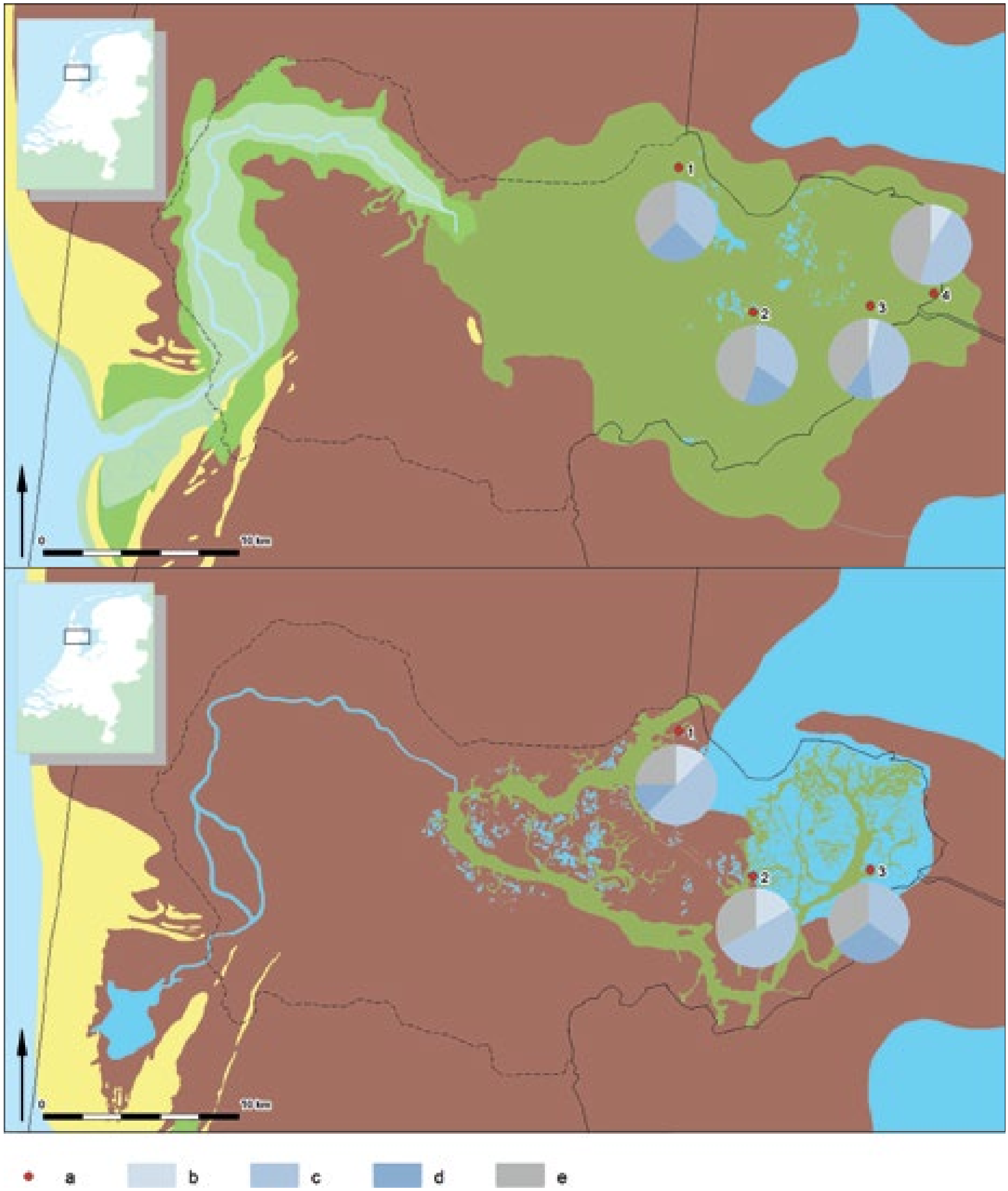

Figure 6.28. Soil moisture levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: dry – medium moist; c: medium moist; d: medium moist – moist; e: indifferent.

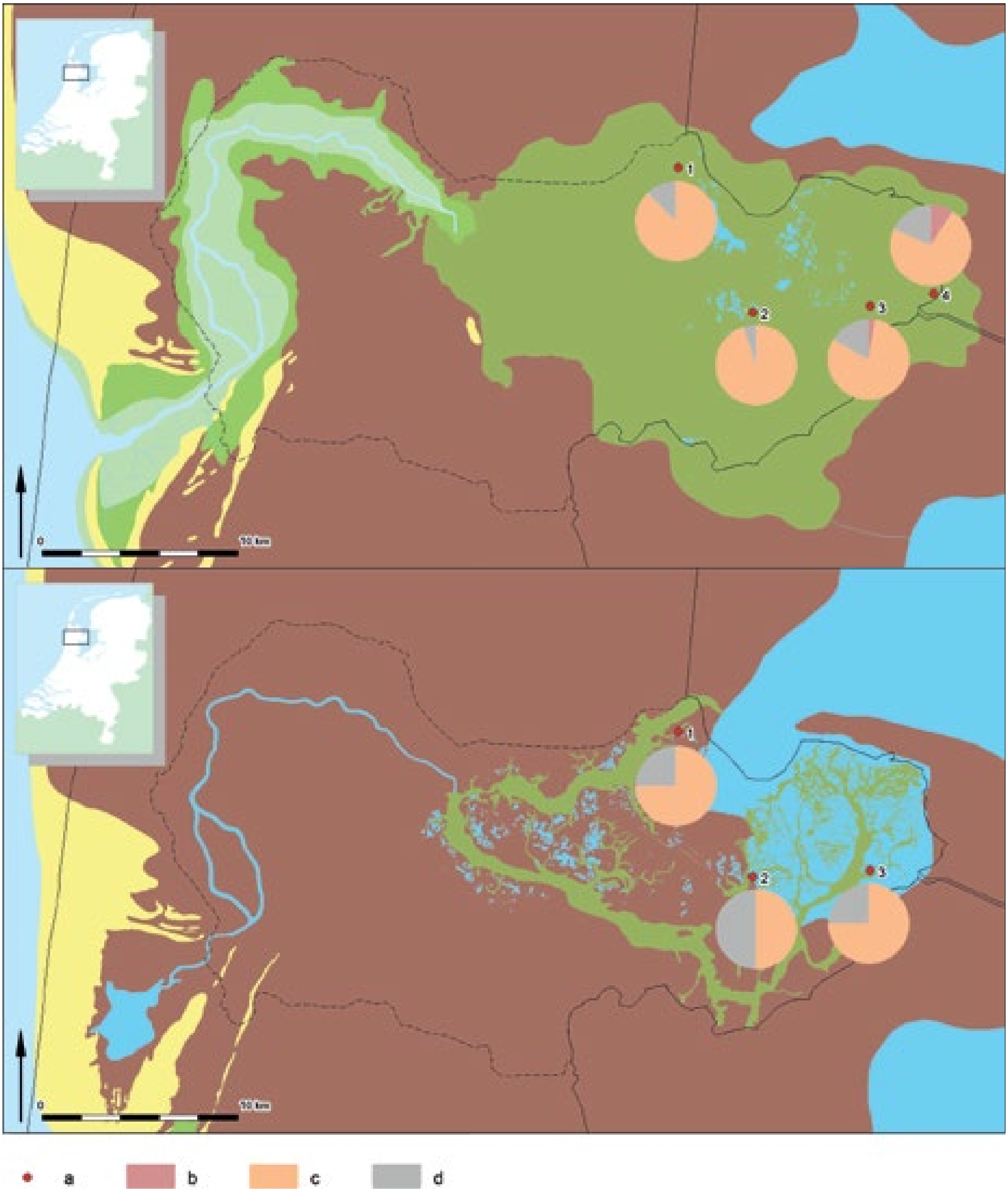

Figure 6.29. Soil pH levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: medium acidic – slightly acidic; c: slightly acidic – slightly alkaline; d: indifferent.

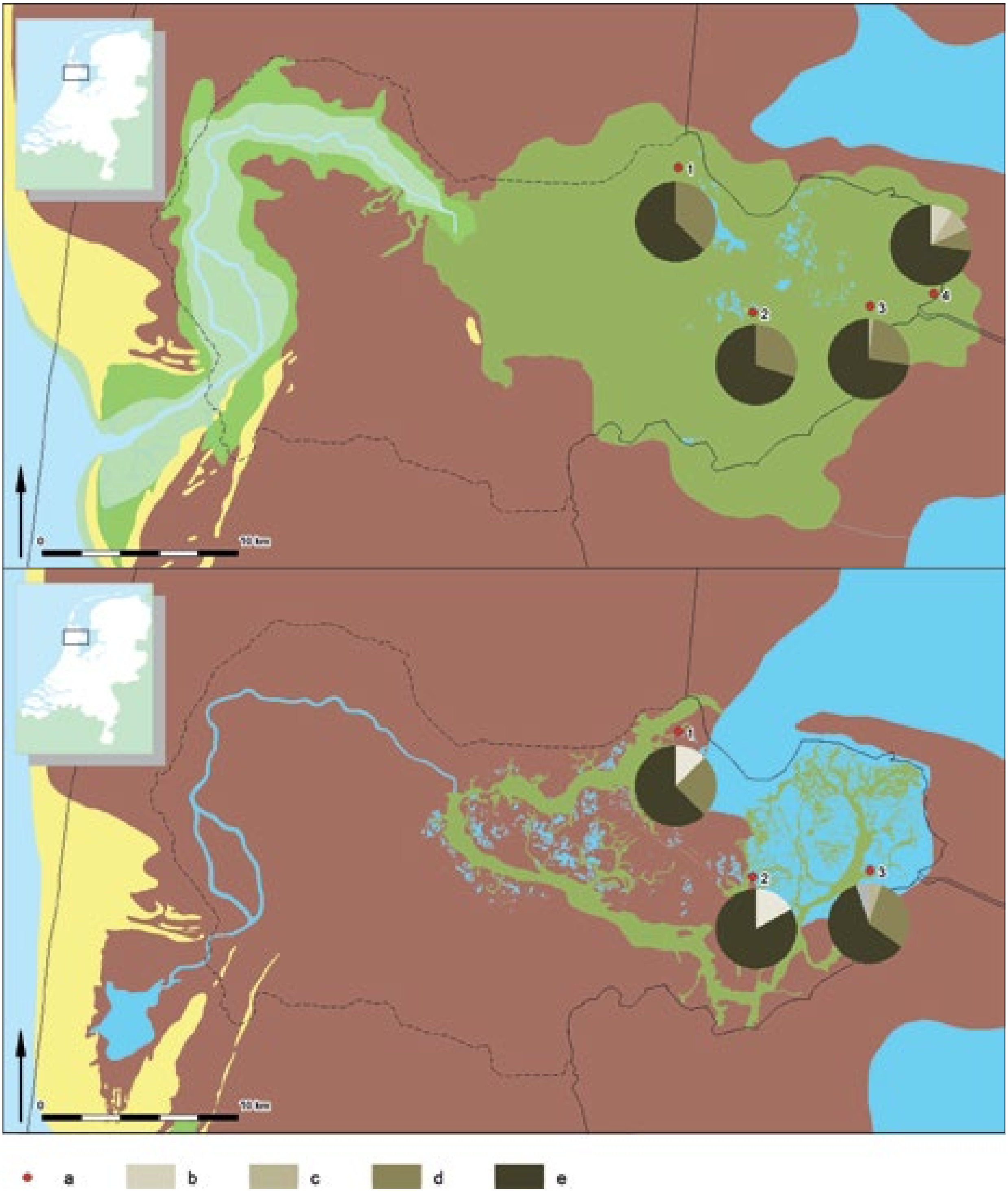

Figure 6.30. Soil nitrogen levels of crop weeds from Middle Bronze Age (top) and Late Bronze Age (bottom) arable fields. 1: Medemblik, n=8; 2: Westwoud, n=20; 3: Bovenkarspel Het Valkje, n=155; 4: Enkhuizen Kadijken, n=11; a: location of excavated site; b: nitrogen poor – medium nitrogen rich; c: medium nitrogen rich – nitrogen rich; d: nitrogen rich; e: nitrogen rich – extremely nitrogen rich.

To summarize, the use of only animal manure by the small-scale settlements of West Frisia was most likely not enough to enhance arable soils. Enrichment of the soil was established based on nitrogen isotope analysis however, showing that fertilizing might not have occurred using only animal manure (Appendix A1.11). A combination of other types of fertilizer with animal manure was probably applied to the arable fields. The possible use of household waste as a fertilizer was already indicated by Buurman based on the presence of small fragments of bone, and ceramics in plough layers (Buurman 1996: 25, 190), which could have assisted the fertilization of arable fields. Therefore, the use of animal manure could have been a viable option for West Frisia, but it should be realized that it was not sufficient on its own to manure all fields on an annual basis.

Other indications for the limited application of manure can be related to the fact that the use of animal manure in waterlogged conditions is not recommended, because nutrients leach quickly (Professional Nutrient Management Group & Environment Agency 2014, 22). Manuring in the vicinity of waterways or ditches can actually cause serious health issues, especially if these ditches are connected to each other, and possibly also form the source of drinking water of a settlement (Professional Nutrient Management Group & Environment Agency 2014, 25). Since West Frisian settlements have many interconnected ditch systems, the use of manure within the settlement could have been a problem.

Concluding, manuring in West Frisia would have consisted of applying a combination of several types of fertilizer, since animal manure alone would not suffice, and could even have contaminated the drinking water supply of the settlement. Alternatively, the use of household waste and green manure will have been additional options for fertilizing the arable fields, or a combination of all these types (cf. section 6.3.5). It is even conceivable that different fields were treated in different ways and frequencies, depending on the distance from the settlement, the type of crop cultivated, and the eventual use of the crop. Similar to the ethnographic examples in section 6.3.5, gardens and fields cultivated with barley are often treated differently than crops grown for straw. Such differences could also have occurred in West Frisia.

Location of arable fields

From section 6.4.1 it has become apparent that arable fields were probably not all located in the immediate vicinity of the settlement, since the reconstructed arable field size areas (0.6 ha) did not amount to the minimum size of arable fields observed in small-scale farming communities (1 ha/household). Of course, the reconstructed field size is also a minimum, due to the differential ground penetrating properties of the ard, so the original field size may have been larger. It could thus not be concluded whether the arable fields were smaller in the Bronze Age than in present-day small-scale farming communities.

However, since more than one cereal was cultivated, and maslin crops are not assumed, different crops would have been cultivated at different arable fields. This division in crop cultivation automatically means that total arable field size (*i.e.* 1.8 ha) would have been divided into smaller separate plots, similar to what is observed in small-scale farming parallels (section 6.3.1). In this case, the reconstructed size of the West Frisian arable field of at least 0.6 ha may reflect only a single smaller and separate plot, not the total area of arable fields owned by the household.

The exact location of arable fields was hard to establish, because it was not always clear whether houses and plough marks at an excavated site were contemporary. However, it can be assumed based on the analysis of Hoogkarspel Tolhuis find spot F (Roessingh in prep.), that some fields were at least in close proximity to the settlement. An indication that fields were probably also located further away from the direct surroundings of the settlement is provided by the observation that burning of arable fields was practiced (section 6.4.2). Since it is unlikely that fields were burned close to the (thatched houses of the) settlement, it can be assumed that these were located at some distance, to a maximum of 2.5 km away (cf. section 6.3.5). It is even conceivable that some fields were only burned in autumn and ploughed in a shallow manner in spring to prepare the soil for sowing (cf section 6.3.2). This practice, and therefore these types of arable field, would then only be recognisable based on a specific type of black layer. More in-depth interdisciplinary research (cf. section 6.4.2; Pronk in prep.) is required to establish these practices and recognise the arable fields which would have been treated with this technique.

6.4.6 Seasonality

Sowing season

It was established in section 6.4.3 that West Frisians cultivated summer varieties of cereal crops. This means that sowing occurred, weather permitting, roughly between February and March (van den Brink 2005; Table 6.7).

Harvesting and burning season

Harvesting of spring sown cereals occurs in August (United States 1997; Table 6.7), with the precise moment depending on the ripeness of the crop which in turn depends on the environmental conditions during the growing season. Harvesting can therefore also occur much earlier in the year than August for crops with short growing seasons.

Emmer wheat, in addition, is usually harvested early in the morning or during the night, since dew present during those times binds the grains to the ear, which reduces losses in this brittle crop (Hajnalová & Dreslerová 2010, 187).
Burning of stubble is performed close after harvest, before weather conditions become increasingly wet. Therefore it is assumed that burning was practiced between late August and (early) September (Table 6.7).

Ploughing, manuring, weeding season

It has not (yet) been possible to establish when ploughing occurred in West Frisia, although micro-morphological research may shed light on this in the future. For now, hypothetical seasonal information from ethnographic parallels is applied to the West Frisian data for further interpretation (Table 6.7). It should be kept in mind that ploughing cannot occur too early in the year in certain clayey areas when the soil is still too wet. Therefore, a slightly later spring ploughing and sowing also remains a possibility.

Manuring was occurring in West Frisia (section 6.4.5), and this needs to happen right before ploughing; a substantial loss of nutrients through leeching can occur when manure is left on the field without being worked into the soil (Brandjes *et al.* 1996). For spring-sown cereals, manure should be incorporated in the soil just before sowing, which, depending on the weather conditions, is performed from late January to early March, preferably a month before the summer crop is sown (Peña Chocarro 1995, 114; Professional Nutrient Management Group & Environment Agency 2014, 22; Table 6.7).

Weeding was not performed very intensively in West Frisia, evidenced by the range of crop weeds present in the botanical assemblages. When practiced however, it is expected to be performed in the early stages of crop growth, which, depending on the time of sowing, lasts from February to May (Table 6.7).

6.4.7 Summary

The arable fields in West Frisia could be reconstructed to a minimum size of 0.6 ha based on ard mark spread and orientation. This size on its own is insufficient to sustain a family (*i.e.* 1-3 ha), but could form a smaller plot of the total owned land by a household. Other fields may have be situated further away from the settlement, probably to a maximum distance of 2.5 km, or half an hour's walk from the settlement. Fields were used several times, shown by the fact that multiple different orientations of ard marks were uncovered at the same location.

The major crops cultivated throughout the Bronze Age are emmer wheat and hulled barley, of which the former increases in frequency in the Late Bronze Age, at the expense of the latter. Very few other cultivated crops were uncovered in West Frisia, which is in line with the observations made in areas such as the North Sea coast and southern Scandinavia. The only possibly cultivated crops in West Frisia include broomcorn millet, linseed/flax, and a rare find of cultivated oat in the Middle Bronze Age. This absence of other cultivated plants in the Late Bronze Age however, in comparison with both the other areas as well as the West Frisian Middle Bronze Age, could be explained by the fewer samples

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ploughing								?	?	?		
Manuring												
Weeding												
Burning												
Sowing												
Harvesting												

	Ploughing occurring most often		Burning occurring most often
	Ploughing occurring less often		Burning occurring less often
	Manuring occurring most often		Sowing occurring
	Manuring occurring less often		Harvest occurring most often
	Weeding occurring		Harvest occurring less often

Table 6.7. Seasonality information regarding crop husbandry practices.

available from this time period.

Ploughing of the fields occurred with the ard in a criss-cross fashion, evidenced by the discovery of many ard marks throughout West Frisia. However, this was not the only possible activity which occurred on the arable fields after harvest and before sowing. Burning of stubble after harvest was also practiced instead of ploughing in some instances, to rid the fields of crop residue in an efficient manner. This practice ensured that weed seeds were destroyed, and that fields were ready and fertilised for the following sowing and growing season. Livestock would not have been allowed to graze on fields at which crop residue burning was intended to occur, since their presence would reduce the amount of stubble available for burning, as well as the efficiency with which weed seeds were burned, due to trampling. Whether this practice was performed in specific regions, time periods, or different crop fields remains unknown, and further research is needed to establish these aspects. Fallow periods in West Frisia were most likely short to absent, indicating an intensive form of land use: possibly more intensive than the short fallow system proposed based on the model of Boserup.

Sowing of crops was performed in spring in both the Middle and Late Bronze Age, and this was probably done by broadcasting or sowing in furrows. Weeding of crops was not very intensive, since many crop weeds were still present amongst the grain.

Harvesting occurred relatively low on the stalk, with a height of 40-60 cm prevailing in both the Middle and Late Bronze Age. The practice of harvesting was most likely performed by reaping with a sickle, or practicing uprooting by pulling the crop from the soil.

After the harvest, it appears that the harvest was stored in different ways at different sites. Most sites in West Frisia stored their grain in a relatively unclean manner (*i.e.* still including many weeds), which is probably due to the limited amount of people (*i.e.* small households) and time available. In Bovenkarspel Het Valkje, however, a difference was observed in that in the Middle Bronze Age, a combination of clean and unclean grain was stored by different households, possibly signifying a difference in household size. In the Late Bronze Age, all households seem to revert back to storing of unclean grain, which may be related to deteriorating weather conditions during this time and therefore (more) restricted time for the harvest. Alternatively, the wetter environment may have been able to sustain less people than in the previous period, which also results in storage of unclean grain. Of course, also a combination of the two factors could be the cause for the observed change.

Grain was probably stored in the western part of the house, since the eastern part of the house is assumed to be the barn part of the house (Chapter 5, section 5.4.3), and grain should not be stored over barn areas. The attic was probably used for storage, since storage of dried grain requires elevated, well-ventilated and dry conditions, and no clear outside storage structures have been identified.

The soil conditions on the arable fields were very favourable for crop husbandry, in both Bronze Age periods, with an absence of saline and acidic conditions, and adequate moisture and nitrogen levels.

Enrichment of the soil was established, indicating the use of fertilizer on arable fields. The fertilizer will most likely have consisted of a combination of animal dung, household waste, and remains of stubble burning.

Crop husbandry practices will have mainly been performed during sowing and harvest time and related activities, which occurred from roughly February-March and August-September.

6.4.8. Discussion

6.4.8.1 Methodology

Crop husbandry practices in West Frisia are mainly reflected in settlement contexts, since off-site locations are rarely excavated. Furthermore, it can be expected that most harvest processing, as well as the storage of this harvest, occurs in or around the house. It is therefore very important that house contexts are sieved systematically during future excavations. Only with data acquired in this manner can more firm indications be obtained of the differences regarding crop processing between households, as well as social organisation of the settlement at large. A combination of magnetic susceptibility, loss-on-ignition, phosphate analysis, and botanical analyses has already been able to show activity areas in relation to crop husbandry (Grabowski & Linderholm 2014). In addition, such data can even provide insight into the potential use of the building, and possible activity areas within it (Chapter 8, section 8.5).

A further methodological step which would help the research towards crop husbandry forward is the interdisciplinary research towards ploughing practices, burning practices, and manuring related to arable fields. By combining disciplines such as micro-morphology, phytolith analysis, and pollen analysis, much information can be gained on how the individual practices were performed, and possibly also shed light on their seasonality. Adequate sampling should be performed to ensure that this multi-proxy approach can be realised.

6.4.8.2 Taphonomy

In section 6.4.1, it was made clear that only the most frequent crops emmer wheat and hulled barley would be discussed in the main text. However, other crops, which were less frequent in the assemblages need not have been equally less important (cf. Chapter 4; Chapter 7).

One of the main reasons that for example linseed/flax was not frequently found in West Frisian settlements could very well be related to taphonomy, not importance or cultivation frequency.

Flax/linseed can be grown for either its seeds (linseed) or it fibres (flax); the quality of one of the two diminishes when the other improves. Alternatively, flax/linseed can be harvested for both purposes, but the quality of fibres and seeds will be lower.

If flax was grown for textile production, it would not be surprising that few remains were found, since harvest would occur before full maturation of the crop: most plants would not have set seed yet. The seeds would derive from the sowing seed required for the following year, which would be obtained from a small part of the crop left on the field after harvest for fibres was already completed. This inherently means that these seed remains are unlikely to become charred.

If flax/linseed was grown for the oil-containing seeds, it is still logical to find few remains if we assess the harvest processing of flax. Flax harvesting and processing would have been performed in bulk annually. Similar to the harvest processing of cereals (section 6.3.4), this means that results from such once-a-year actions will be underrepresented in the archaeological record in comparison to daily activities. In addition, linseed does not require fire for its preservation, as opposed to emmer and barley, and, like other oil-containing plants, preserves poorly in charred form (Buurman and Pals 1974).

The bad preservation of flax/linseed can therefore be related to the original absence of seed on the plant during harvest for fibre and/or low preservation chances of seeds. Linseed is thus unlikely to preserve in general, but will be slightly better represented in uncharred form.

The above examples illustrate the probable gross underrepresentation of linseed in the archaeological record, regardless of the purpose of the plant (Figure 6.31).

Therefore, it must be emphasized that the presence of a few remains of linseed is not necessarily an indication for the unimportance of this crop to subsistence, and that only charred remains do not accurately reflect the cultivation of flax/linseed. Furthermore, the presence of flax/linseed at four Middle Bronze Age West Frisian sites (Bovenkarspel Het Valkje, Enkhuizen, Westwoud, and Hoogkarspel

Watertoren), might actually point towards cultivation in the Bronze Age. The fact that these uncharred remains are uncovered at every site, but in low amounts, may point towards the cultivation of this plant for its fibres. Where this may have been the case, it is important to be aware of flax fibres and woody plant parts in future archaeobotanical investigations of waterlogged material in West Frisia (Chapter 11), which may underline this cultivation practice.

In the Late Bronze Age, no linseed remains were found, but, combining the low chance of finding linseed outlined above with the low number of samples researched, this does by no means indicate that flax/linseed was not cultivated in the Late Bronze Age as well.

Broomcorn millet and oats were also uncovered in low amounts at the West Frisian sites. However, these plants are not affected by taphonomy in the same manner and level as linseed/flax. Broomcorn millet preserves well under waterlogged conditions, where especially its chaff is easily identifiable due to its distinct appearance. The few indications for this plant do indicate that it was cultivated, because it is not a native plant to the Netherlands. The low frequency and number of remains of this plant, however, mean that overall, it was cultivated to a lesser extent than for example emmer wheat and barley.

Cultivated oats can only be distinguished from wild oats by the base characteristics of the rachis. Since these remains are scarcely found, it is hard to determine whether the remains of oats belong to cultivated or wild species. It is therefore unclear whether the many remains of unidentifiable oats species in the West Frisian record belong to the cultivated or wild variety. Thus, it is hard to assess to which extent oats were cultivated in the West Frisian Bronze Age. However, if this crop was cultivated, oats chaff should have been recognised in relatively high amounts in settlement contexts, since these remains preserve well. Since this was not the case, it can be assumed that the cultivation of oats played a minor role in West Frisia.

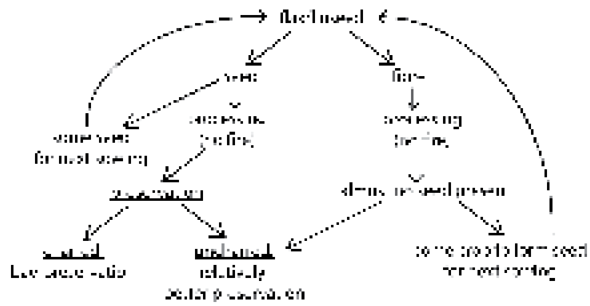

Figure 6.31. Preservation potential of linseed for both its use for fibre or seed.

6.4.8.3 Possible selection criteria for consumption

The range of crops available in the Bronze Age in the area of West Frisia was already examined in section 6.4.1, based on a general comparison with other areas along the North Sea and southern Scandinavian coasts. This comparison has indicated that some differences existed, which may be the result of a conscious selection by West Frisians from the total available crops during this time. This selection may have been made based on criteria including a possible local preference for certain crops, crop-specific growing possibilities within the area, and access to the different species of crops. Growing conditions are, however, not a likely reason, since climate and geographical location of especially the North Sea coast and southern Scandinavia are comparable to West Frisia. This means that only local preference and access to crops remain as possible reasons for the range of crops observed.

Overall, West Frisia stands out in comparison to other areas based on the appearance, absence, or frequency of certain crops that appear to be unique for West Frisia.

For example, the range of cereals in West Frisia is rather limited in comparison to other areas, actually only including emmer wheat and hulled barley, with a minor addition of naked barley and broomcorn millet in the Middle Bronze Age. In other coastal areas, spelt wheat and einkorn also belong to the range of crops.

Vice versa, crops present in West Frisia are not always present in neighbouring areas during this time. For example, cultivated oat was established in one instance, as well as linseed at four sites (Bovenkarspel Het Valkje, Enkhuizen, Westwoud, and Hoogkarspel Watertoren). Especially linseed is more dominant than in other areas, but this may be related to the good preservation of waterlogged remains present in West Frisia (section 6.4.8.2). It is debatable whether people in West Frisia preferred this small range of crops, since the larger the range of crops, the better the spread of risk is accomplished. In essence, West Frisia appears to have a rather limited range of crops which may in fact be related to its relatively isolated position in the Netherlands, which would have provided access to some, but not all crops available in the Bronze Age. Perhaps since animals were imported from the eastern part of the Netherlands (Chapter 5, section 5.4.3), it can also be assumed that crops may have originally derived from there, which would restrict the range of crops in West Frisia to what was available in eastern regions. It is interesting to investigate whether crops from these locations resemble the West Frisian crop range, and this will be attempted in Chapter 9.

6.4.8.4 Other reasons for crop husbandry

In this chapter, the main focus was on subsistence production for human consumption. Besides this reason, of course other reasons exist for the production of crops. They are shortly discussed here for the crops: emmer wheat, hulled barley, and linseed/flax.

Animal consumption
Depending on the number of non-grazing animals, additional fodder may have been required for certain periods of time (Chapter 5, section 5.3.5). Cereal crop remains (*i.e.* straw) from crops grown for human consumption can be used as fodder, although, as stated in section 6.3.3, not every crop species is suitable for this purpose. Emmer wheat for example, is tough and sharp and not used for fodder purposes in for example Slovakia and the Mediterranean (Hajnalová & Dreslerová 2010, 187; Halstead 2014, 86), but is used in other activities (see below). Barley straw on the other hand, is widely accepted as a valued fodder crop (Ertuğ 2000, 177; Halstead, 2014, 68). The straw of flax is unfit for animal fodder, but flax seeds may be given to livestock (Oplinger *et al.* 1989). Chaff of cereal crops is usually not consumed by livestock, unless it is mixed with water. Wild oat (*Avena fatua*) has, until recently, been known to be harvested and foddered to livestock in for example Spain (Peña Chocarro 1995, 99).

Raw material
Emmer wheat straw, which is not suitable for animal fodder, is often used as a raw material for *e.g.* thatching or basketry (Hajnalová & Dreslerová 2010, 187; Stephens & Langlands 2011, 373; Halstead 2014, 86). Chaff of either emmer wheat or barley may be used as fuel or as temper in pottery making (Fuller *et al.* 2014, fig. 10). Flax cultivation is often linked to the excellent fibres which can be obtained from this plant. These fibres are used in textile production (*i.e.* linen).

6.5 RECONSTRUCTION OF CROP HUSBANDRY

The reconstruction of crop husbandry was achieved by comparing the results of the new analyses made in this chapter with the current model's main components. The contribution of the different proxies applied in this analysis as well as the general approach of this chapter are outlined below. Furthermore, the validity of each of the main components of the current model of West Frisian crop husbandry is assessed in section 6.5.2. Finally, the valid current main components as well as the components which were incompatible with the new results and were reformulated are combined to form a new model for crop husbandry in Bronze Age West Frisia (section 6.5.3).

6.5.1 Contributions of proxies and approach to the reconstruction of crop husbandry

Ethnography has, as in other chapters, provided valuable information on the basic crop husbandry practices in small-scale mixed subsistence farming communities from around the world. The added use of ethnobotany has enabled an even more detailed expectation of specific practices regarding the cultivation of emmer wheat and hulled barley, as well as quantitative values for harvest yields, losses, etc. Ecological data on crop weeds has provided information on the favourable soil characteristics of arable fields, showing that West Frisian farmers were very capable of finding appropriate locations for the cultivation of their crops throughout the Bronze Age. The biological information on crop weeds has identified crop husbandry practices such as spring sowing, harvesting at low heights, and the (near-) absence of fallow periods, enabling the recognition of specific practices performed by West Frisian farmers. Archaeobotany has provided a clear overview of the range of crops available in neighbouring areas to West Frisia. A comparison between these regions has enabled the identification two specific crops selected by West Frisian farmers, even though a wider range was available during this time period. In addition, a new crop husbandry practice for West Frisia and the Bronze Age period in the Netherlands was recognized (*i.e.* stubble burning) through, phytolith and pollen analysis, and micro-morphological analysis. A further result from the detailed analysis of crop and weed remains from house contexts in this chapter has enabled the possible identification of different types of social organisation of harvest processing practices within one settlement. Features uncovered during archaeological excavations have provided indications for possible available arable field sizes and shapes, as well as the manners in which the harvest may have been stored. Isotope studies finally, have confirmed the enrichment of arable field soils by the addition of fertiliser, as well as the recognition of import of domestic animals to West Frisia from more eastern areas.

In this chapter, the main approach was similar to the previous two chapters in that it was attempted to show the complexity of crop husbandry through the analysis of its basic activities, with the aid of different proxies. Ethnographical parallels have again proven to be invaluable in creating an expectation of the different aspects related to crop husbandry, especially those that are not (immediately) apparent based on an archaeobotanical assemblage. The assessment of the effects of archaeological methodology and taphonomy on such an assemblage has created a better understanding of why certain crop husbandry related activities are not visible (anymore). The analyses made in this chapter have covered the entire crop husbandry subsistence strategy and have resulted in a complete image of the different elements of this main form of food production in the Bronze Age.

6.5.2 Assessing previous main components

The results produced in this chapter regarding the role and praxis of crop husbandry in Bronze Age West Frisia are compared to the main components of the current model in this section. Whenever a current main component is not in concurrence with the newly acquired results, the former is reformulated to match the latter.
Main component 1 was formulated as follows:

(1) Arable fields in West Frisia were sometimes wet and contained only one crop species at a time.

Based on the analysis of crop weeds, it is clear that arable fields in West Frisia were not wet during the growing season. It is unclear whether the waterside vegetation observed in the assemblages arrived at the settlement together with the harvest, or whether it is a reflection of other practices. What is apparent is that crops were harvested relatively low, which means that cereal straw may have been used for purposes including raw material and fodder. Since the use of emmer straw (*i.e.* raw material) differs from the use of barley straw (*i.e.* fodder), the chance that the two crops were grown mixed within the same field is reduced. This observation has provided additional indications that indeed crops were grown on separate fields. Therefore, main component 1 is only partly reformulated to match the new results:

(N1) Arable fields in West Frisia possessed very favourable conditions for crop husbandry, without excessive moisture during the growing seasons, and only contained one crop at a time.

Main component 2 was formulated as follows:

(2) West Frisian crops were mainly emmer wheat and hulled barley for most of the Bronze Age.
(2a) In the Middle Bronze Age, emmer wheat and hulled barley were of equal importance.
(2b) In the Late Bronze Age, solely hulled barley was cultivated.

Based on the re-analysis of the West Frisian botanical samples, emmer wheat and hulled barley were indeed most frequently present. However, emmer wheat, rather than hulled barley, becomes more frequently present in the Late Bronze Age samples. The cultivation of emmer wheat in the Late Bronze Age is not exclusive either, since hulled barley still appears during this time, only at slightly lower frequencies. Linseed was also cultivated, but it is hard to assess its importance in relation to the cereals, due to its bad preservation characteristics. The importance of crops should thus not be directly related to their frequencies. Main components 2, 2a, and 2b are (partly) reformulated accordingly:

(N2) West Frisian crops were probably mainly emmer wheat and hulled barley, which are present at equal frequencies in the Middle Bronze Age, whereas in the Late Bronze Age, emmer wheat becomes more dominant.

Main component 3 was formulated as follows:

(3) Sowing of crops occurred in spring.

Based on the analysis of the old and new data on crop weeds, it can be concluded that indeed crops were most likely sown in spring. Therefore, main component 3 does not require reformulation.

Main component 4 was formulated as follows:

(4) Fertilising fields was achieved by applying a combination of household waste and animal dung.

Based on new nitrogen isotopic data, it was confirmed that fertilisation of fields occurred in West Frisia. Although the specific type of fertilizer could not be established based on this analysis, it was clear that animal dung alone would not suffice. The limited amount of livestock kept per household would simply not have been able to produce enough to manure all the arable fields. Additional fertilizer would have to be supplied, most likely in the form of household waste. This conclusion matches with the postulated main component 4, and therefore it does not need to be reformulated.

Main component 5 was formulated as follows:

(5) Harvesting ripe crops was performed by reaping low on the stalk with a bronze sickle, and in the Late Bronze Age, by uprooting crops.

Based on the absence of archaeological evidence of (bronze) sickles, it was not possible to establish what type of harvesting tool was used in West Frisia. However, the low harvesting height observed indicates that such a tool must have existed. Uprooting may also explain the low harvesting height and could have occurred as well. Since the average harvesting height does not seem to change between the Middle and Late Bronze Age, it is unclear whether a definite change in harvesting practices occurred between these periods. A re-formulation of main component 5 is in order:

(N5) Harvesting ripe crops was most likely performed by reaping low on the stalk or by the uprooting of crops.

Main component 6 was formulated as follows:

(6) Processing of the harvest occurred in and around the house and harvest was stored in sheaves.

Based on the analysis of crop processing waste and accompanying weeds in the assemblage, it is assumed that daily harvest processing occurred in and around the house. The bulk processing before storage of the crop however, could either occur on the fields or within the settlement. The reflection of crop processing waste indicate that in most instances, crops were stored in an unclean state, which indeed means either in ears or sheaves. However, in Bovenkarspel Het Valkje, the remains from some houses show that crops, in the Middle Bronze Age at least, were also stored in a clean state, or in spikelet form. Main component 6 is therefore reformulated as follows:

(N6) Processing of the daily harvest occurred in and around the house, and the harvest was either stored in ears or sheaves, but occassionally also in cleaned spikelet form.

Main component 7 was formulated as follows:

(7) In the Late Bronze Age, people were not able to practice crop husbandry to the extent required to complete subsistence.

Based on the harvest processing waste in the Late Bronze Age, fewer people and/or less time were available to process the harvest to a relatively clean state. Both this decrease in inhabitants and/or unfavourable weather conditions for growing and harvesting the crop could be related to the deteriorating environmental conditions in the Late Bronze Age, which was established based on the landscape reconstruction (Chapter 2). There are, however, no indications that the people that were still inhabiting West Frisia during this time could no longer sustain themselves: the arable fields still consisted of favourable soils for crop husbandry based on the present crop weeds. The current main component and the new results are not compatible and main component 7 is therefore newly formulated:

(N7) In the Late Bronze Age, the total acreage of available arable land was reduced, so fewer people were able to practice crop husbandry to a satisfactory level; the quality and conditions of these remaining fields were, however, still favourable.

Main component 8 was formulated as follows:

(8) Stubble burning may have been applied to clean arable fields after harvest for the subsequent sowing season.

Based on a combination of micro-morphological, phytolith, and pollen analyses, the likelihood of the practice of stubble burning was indeed established in one instance in West Frisia. The seasonality of this practice, as well as other details regarding its execution and spatial organisation remain to be investigated. In the meantime, main component 8 is reformulated as follows:

(N8) Stubble burning was practiced in West Frisia to clean arable fields, although the extent and seasonality of it are still unknown.

Based on the above comparison, most of the main components of the model of Buurman remain valid, or only require minimal adjustments. However, some new insights are also gained in this chapter, and together, the accurate current and new main components are combined and integrated to form the new model for crop husbandry.

6.5.3 New model for crop husbandry

Crop husbandry formed the main food strategy in the small-scale farms of West Frisia in the Bronze Age, providing people with staple food year-round. The cultivated crops in West Frisia mainly consisted of emmer wheat and hulled barley, with a possible addition of linseed and millet. Emmer wheat appears to become more dominant in the Late Bronze Age. The available crops were cultivated on separate field plots of a minimum of 0.6 ha, which is postulated to have amounted to a total cultivated area of 1-3 ha per household, with an average of 1.8 ha. Fields were likely located both close to the settlement and further away. The presence of gardens is expected, although it has not (yet) been identified. This difficulty of identification may be related to the different manner in which these plots are usually tilled (*i.e.* by hand or hoe), and planted (*i.e.* with vegetables), which both are hard to recognise in the archaeological record.

Arable fields were cultivated several times at the same location, which started with ploughing the soil with an ard in spring to prepare the seed bed. Ploughing during this time was performed in a shallow manner, since ploughing at a deeper level would disrupt the soil. Sowing of the summer cereals would occur by broadcasting seeds or sowing the seeds in furrows, after which light harrowing was performed to cover the grain. Weeding was not practiced intensively, but would probably occur several times during the growing season to remove the most evasive weeds. Harvest time would start in late July, by reaping the crop relatively low on the stem, possibly with the use of sickles, or uprooting practices. Directly after harvest, the arable fields were either ploughed, or the stubble was burned, both in order to clear the fields for subsequent sowing in spring. Alternatively, fields were left to lie fallow, but if this was practiced, fallow periods probably only lasted a year.

All the crop husbandry practices together indicate that land use in West Frisia can be characterised as an intermediate form between a short fallow system and annual cultivation, since activities of both land use types are represented.

After harvest, the crops were processed in bulk on the fields or at the settlement, after which they were stored on attics in the western part of the houses at the settlement. The previously postulated role of structures related to ring or post hole ditches in storing of harvested cereals could not be confirmed. Storage of crops was most often performed in an unclean state by small households, meaning that it was stored in ears or sheaves. However, some households were large enough and/or had enough time to store their grain in a clean state (*i.e.* spikelet form), requiring less daily labour to process the grains for consumption purposes. In the Late Bronze Age, all households appear to revert to being small and/or having less time to harvest, which may very well be related to the deteriorating weather conditions during this time, reducing the amount of appropriate land for crop husbandry and therefore subsistence, in West Frisia.

The soil conditions of the arable fields were, however, favourable in both periods of the Bronze Age, indicating that the inhabitants of West Frisia were very well able to sustain themselves based on crop husbandry. Furthermore, besides providing a stable food source throughout the year, crop husbandry may also have provided extra sources of fodder for livestock in winter months, or sources of raw material for other activities.

Crop husbandry may therefore be considered as possibly the most integral part of Bronze Age subsistence, both because of its many activities which are performed to ensure a good harvest and stable food source, but also the food it provides for both human and animal consumption, and as a source of raw material for home and, eventually, hearth.