Sowing the seed ? : human impact and plant subsistence in Dutch wetlands during the Late Mesolithic and Early and Middle Neolithic (5500-3400 cal BC)

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2. Central river area

2.1 Geology and palaeogeography of the central river area

2.1.1 Subsurface

This paragraph discusses the relevant geology and palaeogeography of the central river area. The central river area is located in the Rhine/Meuse delta in the central part of the Netherlands (Alblasserwaard). The main archaeological sites of this region and period are Hardinxveld-Giessendam Polderweg, Hardinxveld-Giessendam De Bruin, Brandwijk-Kerkhof and the Hazendonk. Sites of minor importance for this study are Bergambacht, Goudriaan, Zijdeweg, Meerdonk and Rechthoeksdonk.

The Pleistocene surface in the region consists of calcareous sand and gravel deposits (Kreftenheije Formation) deposited during the Late Pleniglacial, Late Glacial and earliest Holocene by a joint Rhine-Meuse river system (Busschers *et al.* 2007). The top of the sand grades into loam and clays that contain an admixture of coarse sand (Wijchen Member, Kreftenheije Formation; Törnqvist *et al.* 1994; Berendsen and Stouthamer 2002). Inland aeolian dune complexes (river dunes; Delwijnen Member, Boxtel Formation) locally overly the Wijchen Member along Late Glacial and earliest Holocene channels. The dunes have a Younger Dryas age of formation, possibly extending into the earliest Holocene. All major archaeological sites discussed in this chapter are located on such inland dunes, and most other dunes were occupied during the Mesolithic and/or Neolithic as well (Verbruggen in prep.). As the earliest Holocene landscape became buried by deltaic deposits during the Holocene, the dune complexes remained isolated high grounds within the delta plain for several millennia (Berendsen *et al.* 2007; Jelgersma 1961; Mol 2001, 2003; Van de Plassche 1982; Verbraeck *et al.* 1974; Van der Woude 1983).

The Holocene subsurface in the central river area consists of fluvial deposits and lagoonal peat (the Echteld Formation and the Nieuwkoop Formation respectively). Rhine and Meuse deltaic channels delivered clay and sand to the area. These channels repeatedly shifted course through crevassing and avulsion. As a result, several generations of sandy channel belts are preserved, showing an anastomosed network (Berendsen and Stouthamer 2000, 2001; Mol 2001; Törnqvist 1993; Van der Woude 1983). The channel belts are encased by freshwater floodbasin sequences, which show intercalations of fluvial clays and local peats. The clays were deposited as shallow lake fills, crevasse splays and levees. The peat varies in composition between *Alnus* peat, *Phragmites* peat and gyttjaic shallow lake fillings.

During the Holocene, continued fluvial sedimentation and peat growth occurred as a result of the gradual rise of the ground water level, indirectly under influence of the rise of the sea level. Rates of groundwater rise decreased over time, reflecting global sea level rise and local land subsidence trends (Cohen 2005a; Jelgersma 1961; Louwe Kooijmans 1974; Van de Plassche 1982; see fig. 2.1). The first extensive peat growth in the central river area started at *c.* 6400-6200 BC (Cohen 2005a; Van Dijk *et al.* 1991; Van der Woude 1983). From *c.* 4350 BC onwards the partial closure of the beach barrier system (see paragraph 3.1) and the position of the main deltaic rivers along the rims of the delta (Berendsen and Stouthamer 2000; Törnqvist 1993) allowed for relative increased peat growth in the central river area (Bosch and Kok 1994). The gradual rise of the ground water level resulted in many of the inland dunes to submerge and become covered by peat during prehistory. The particular submergence and burial history of the inland dunes resulted in stratigraphical separation of the various occupation periods at single sites. Figure 2.2 shows the palaeogeographical development of the delta of the Rhine and Meuse from *c.* 5500 to 3800 BC and the location of the sites presented in this chapter. Appendices I, II and III provide detailed, local information on the geology and palaeogeography of the main sites Hardinxveld, Brandwijk-Kerkhof and the Hazendonk.

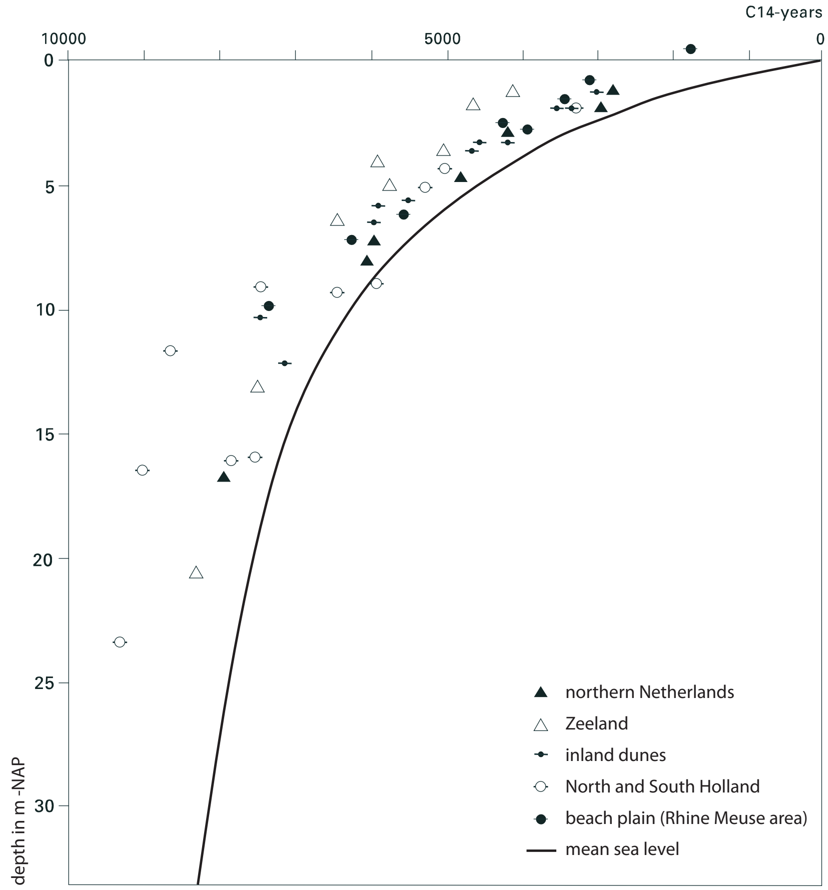

Figure 2.1 The Holocene sea level rise of the North Sea (Jelgersma 1979).

2.1.2 Anastomosing river system

During *c.* 7000-2500 BC, the central Rhine-Meuse delta hosted an anastomosing river system in which multiple channels functioned coevally (Bosch and Kok 1994; Makaske 1998; Törnqvist 1993). In the setting of the Rhine-Meuse delta, this type of river system is associated with a high rate of the groundwater-level rise, submerging of the landscape, and creation of sediment accommodation space in such amounts that river sedimentation alone could not fill the entire delta area (Cohen 2005a; Gouw 2008; Törnqvist 1993). As a result, a divergent channel network developed. The channel network enclosed floodbasin marshes and lakes that allowed for steady sedimentation along the levees of the channels, and peat formation at distance from the rivers (*e.g.* Berendsen and Stouthamer 2000, 2001; Makaske 1998). In the floodbasins, the water table was at the surface for most of the year (soil levels in peats are rare). The levees were above that water table for most of the year and were relative narrow. Consequently, breaching of levees occurred frequently (Makaske 1998; Stouthamer 2001). The anastomosing river system was characterised by a combination of many relative narrow, non-meandering ('straight') small channels and few larger meandering main channels positioned exclusively along the edges of the delta (Berendens and Stouthamer 2001).

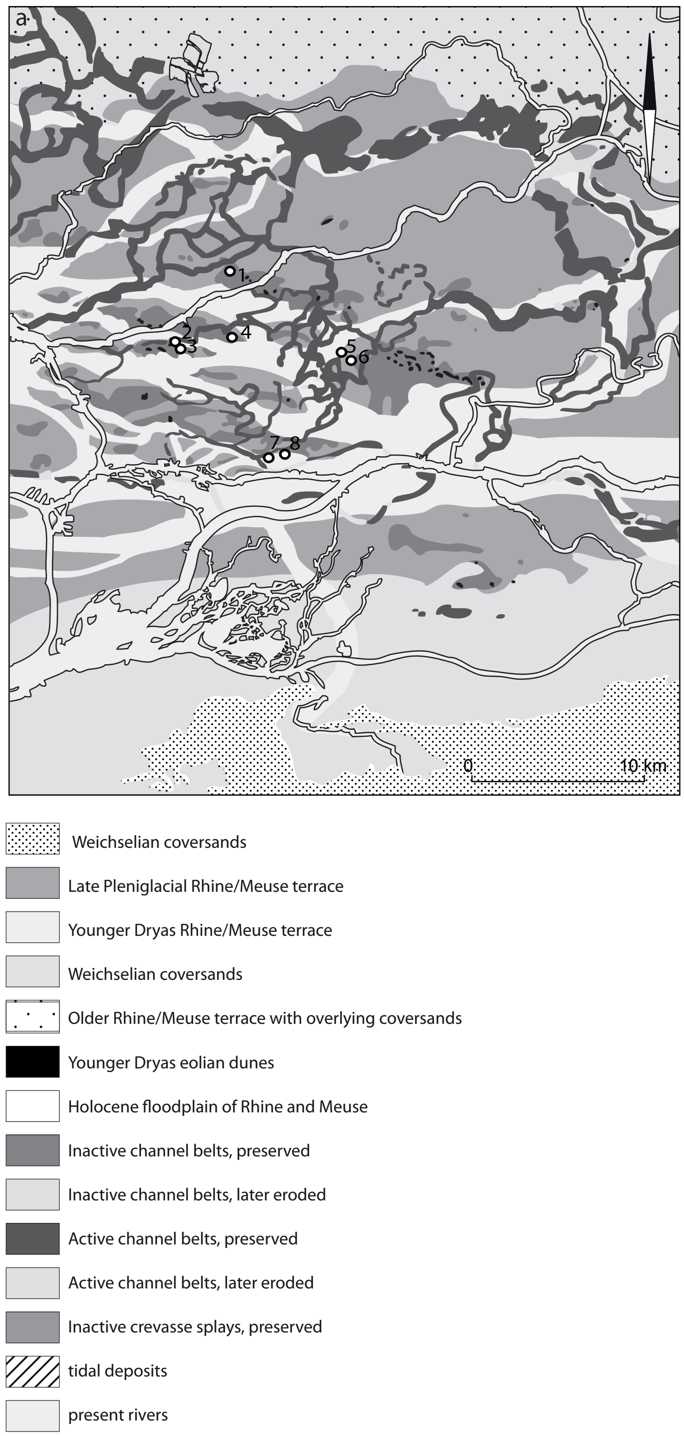

Figure 2.2 part 1.

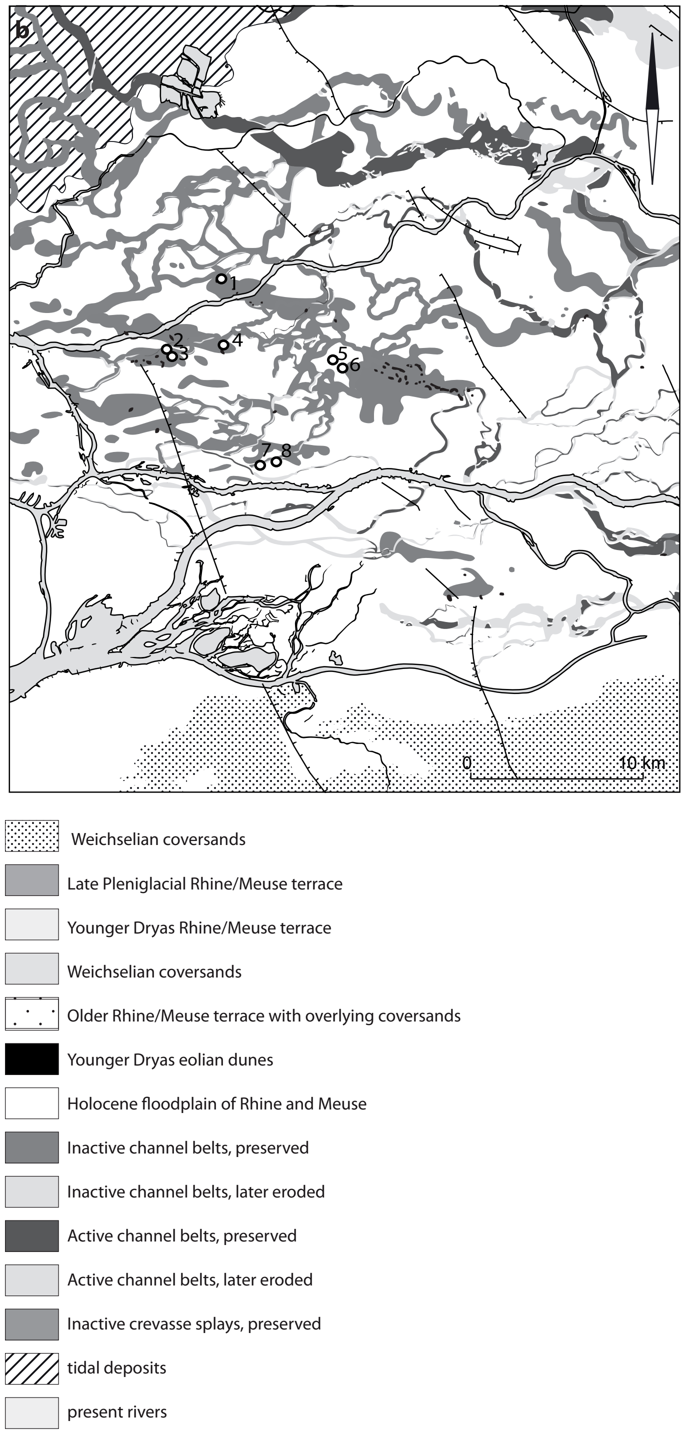

Figure 2.2 part 2.

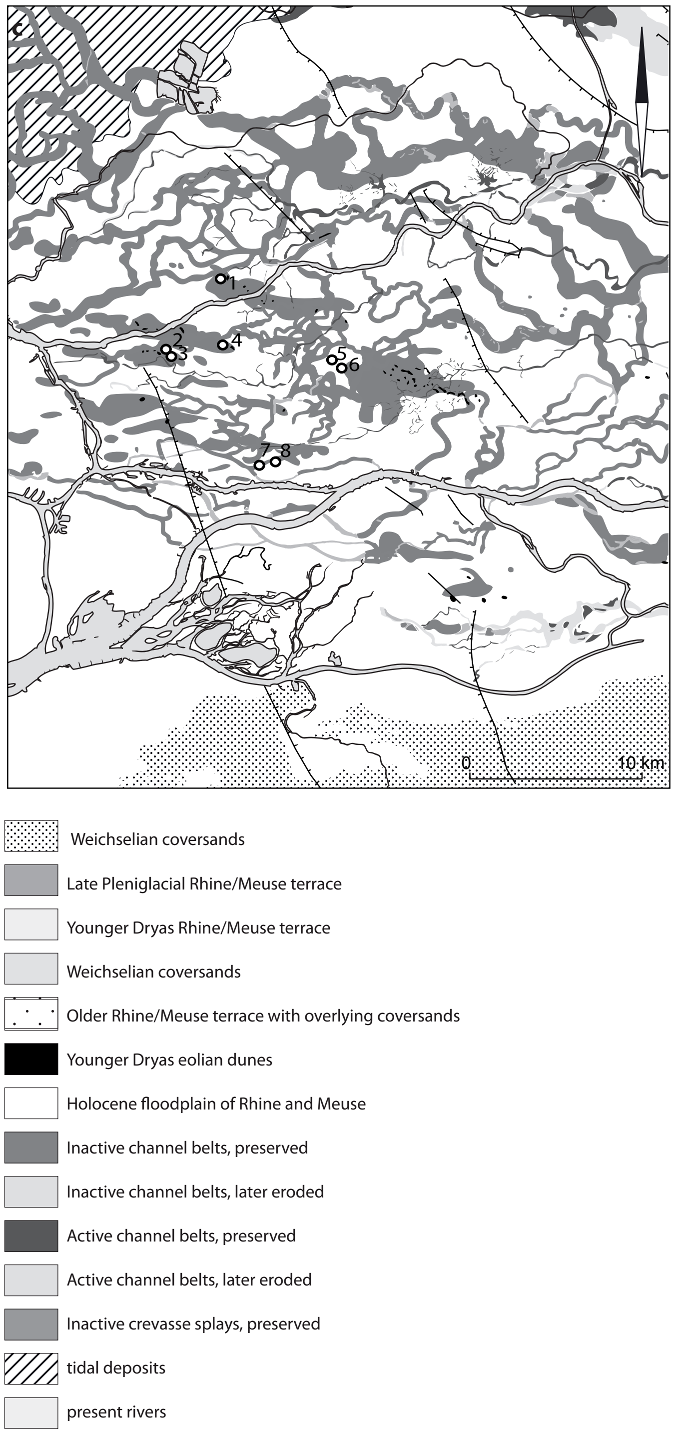

Figure 2.2 The Rhine/Meuse delta, palaeogeographical reconstruction for a) 5500 BC, b) 4300 BC and c) 3800 BC (after Berendsen and Stouthamer 2001). 1 = Bergambacht, 2 = Zijdeweg, 3 = Meerdonk, 4 = Brandwijk-Kerkhof, 5= Goudriaan, 6 = Rechthoeksdonk, 7 = Hardinxveld-Giessendam Polderweg and Hardinxveld-Giessendam De Bruin and 8= the Hazendonk, part 3.

In the central river area, narrow channel belts dissected large floodbasins, lakes and backswamps (Berendsen and Stouthamer, 2000, 2001; Makaske 1998; Mol 2001, 2003; Törnqvist 1993). A number of river systems was active during the studied period[1] (Berendsen and Stouthamer 2001), mainly of a straight type and all part of the anastomosing networks. These river systems were associated with numerous crevasse channels that were present within a 5 km distance during the occupation of the sites studied. The presence of fluvial channels near sites must have been relevant for accessibility of the sites, since they probably functioned as main transport routes.

The repeated shifting of river courses in the area (avulsion; Berendsen and Stouthamer 2000, 2001; Törnqvist 1993) led to the preservation of abandoned channel belts.[2] In the central river area, avulsions occurred between 6000-4300 BC (Stouthamer 2001), thereafter new channels originated from (far) upstream avulsion events.

In the central river area, floodbasin sequences of the time frame of interest contain significant amounts of crevasse-splay deposits (*e.g.* Gouw and Erkens 2007; Törnqvist 1993), but it is unclear whether these are to be regarded as fills of floodbasin lakes or as splay-fans like upstream counterparts, that briefly were dry terrains (pers. comm. Cohen and Bos, Utrecht University, 2008). Typical individual crevasse-splays have a sand-filled channel of 10-20 metres wide, encased by a splay of clay (50-100 metres). The time contained within a splay is at best some hundred years, including a few years with large discharge peaks (incidental deposition) during which the crevasse occurred and healed.

2.1.3 Types of dry terrain in the anastomosing river system

In the central river area, several types of dry terrain were present that stood out from the marshes during the Middle Holocene and that may have been used for occupation and agricultural practices (see also the paragraphs above). The first category of dry terrain comprises the inland dunes, for which there is plenty of evidence of occupation. A second type of dry terrain consists of the levees along the river channels. Their location and relative elevation is related to active river channels. A third category comprises alluvial ridges marking recently abandoned channel belts. Occupation of channel belts upstream of the central river area is demonstrated for the Middle Neolithic and Bronze Age (*e.g.* Bulten 1998; Meijlink and Kranendonk 2002, 604-612), but not for the Early Neolithic. This difference may be related to decreasing rates of groundwater rise over time, which made that younger channel belts remained superelevated for much longer time periods (millennia in the Late Holocene) than older channel belts (centuries in the Middle Holocene). A fourth possible category comprises crevasse splays that developed due to the breaching of a channel, although these probably only stood out for very short periods (discussed above).

2.1.4 Ground water level and marine influence

The ground water level in central river area was controlled by (1) the mean sea water level downstream, (2) the tidal range and (3) the river discharge from upstream (Cohen 2005a). In the central delta, the rate at which groundwater level rose echoed primarily the downstream eustatic sea level rise and local land subsidence (Cohen 2005a; Jelgersma 1961). Superimposed minor acceleration and deceleration in the trends were due to changes in tides (due to changes in position and configuration of tidal inlets; the 'floodbasin effect'; Van de Plassche 1995) and changes in received river discharge (due to shifting of channels away and towards the area of interest; Berendsen *et al.* 2007). In the west of the central river area

1 The Benschop and the Graaf river system were active during *c.* 6220-4070 BC (7300-5350 BP) and *c.* 3800-2000 BC (5000-3700 BP) respectively.

2 A channel belt is the sedimentary product of a river course. Abandoned channel belts in the Rhine-Meuse delta are ribbons of sand. The bases of larger channel belts are incised into the Pleistocene subsurface. The channel belts are insensitive to compaction, in contrast to the floodbasin sequences that encase them. Consequently, the levees of abandoned channels stand out above the surrounding floodbasin as alluvial ridges for considerable time.

(x coordinate = 100), groundwater level rise registered more or less the rate of sea level rise from *c.* 5650 BC onwards (Berendsen *et al.* 2007; Cohen 2005a). In the very east of the central river area (x coordinate = 115), regional groundwater stood up to one metre higher (Cohen 2005a; Van Dijk *et al.* 1991).

During 5500-3400 BC, the water level in the central river area was not strongly influenced by tidal activity, which was due to the relative distance of the area to the coast, a buffering effect of tidal amplitude by tidal lagoon systems immediately downstream of the area, and the groundwater retaining effect of fresh peats (Van de Plassche 1995). This is confirmed by palaeoecological studies (Van der Woude 1983), sedimentary studies (Bosch and Kok 1994; Törnqvist 1993) and spatio-temporal trend analysis of groundwater levels across the delta (Cohen 2005a). Comparative diatom analysis downstream in the central river area indicate considerable differences in marine influence over a distance of 6 km west of the river area (Peeters 1986), which implies that the sites in the central river area were just out of the zone where marine influence resulted in occurrence of brackish conditions. The vicinity to marine areas is further investigated through analysis of archaeobotanical remains (see paragraph 2.8.2 below).

2.2 Bergambacht

2.2.1 Introduction

Bergambacht is located in the southern part of the Krimpenerwaard, *c.* 5 km north of Brandwijk-Kerkhof. In the subsurface of Bergambacht, an inland dune complex is present, consisting of at least three dunes with a maximal height of *c.* 2.5 m +NAP. A prospection demonstrated prehistoric occupation at the location 't Slot (coordinates 113.425/438.125). The occupied dune has a height of *c.* 0.5 m -NAP and was separated from near inland dunes by a channel.[3] Indications of occupation comprising charcoal, bone remains, pottery remains and flint were concentrated in an area measuring 25 x 50 metres at the northern side of the dune. Charcoal remains were spread over a larger area. Pottery remains have been dated to the Neolithic in general (5300 to 2000 BC). Charcoal found together with the pottery was dated to the Late Neolithic (3100 to 2750 BC[4]; Dasselaar and De Koning 2005). Later small-scale research activities did not result in more specific information (Tuinstra and Van den Borre 2004). The archaeobotanical data of Bergambacht consist of a pollen diagram and a set of macroremains. The two data sets were sampled at different locations and with different goals.

2.2.2 Materials and methods of the pollen analysis

The data of the pollen analysis of Bergambacht were kindly made available by Alterra, the organisation that was responsible for the archive of K. Koelbloed, former employee of the Stichting voor Bodemkartering. The goal of the pollen analysis in 1974 was to produce a geological map rather than producing a detailed vegetation reconstruction. The pollen core was sampled at the location 114.230/438.455. Outcrops of an inland dune complex are present at 1 km distance both in western and southern directions from the sampling location. In the scope of this research, recalculation of the original diagram[5] took place, based on an upland pollen sum (dryland trees, shrubs, herbs and spore plants) of at least 200 pollen grains for each spectrum. The depth of the sediment is given in cm below surface. The level of the surface is estimated at 1.2 m -NAP (based on information of the geological map). The spectrum interval of the pollen core varies between 30 and 60 cm. The diagram is not dated.

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3 This channel was probably part of the Schoonhoven channel, active between 3700-2500 BC (Berendsen and Stouthamer 2001).

4 AA-46476 (GU9636), 4315 ± 55 BP (Dasselaar and De Koning 2005).

5 It is unknown to the author whether the diagram has been published before.

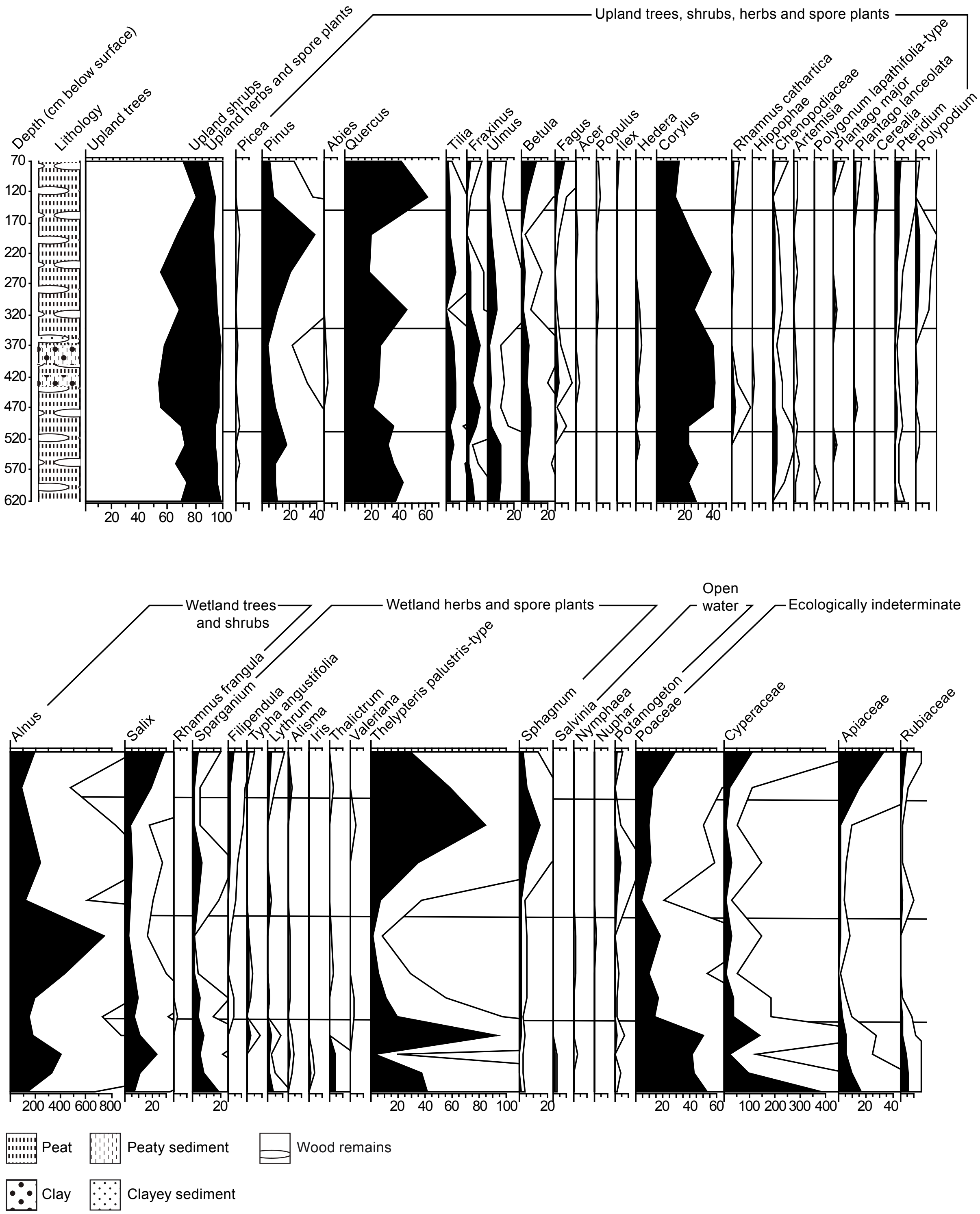

Figure 2.3 part 1.

2.2.3 Results of the pollen analysis

Figure 2.3 shows the pollen diagram from Bergambacht. The diagram is divided into four zones. In zone I (6.20 to 5.10 m below surface), *Quercus* sp., *Corylus* sp. and *Ulmus* sp. dominate in the extra-local dryland vegetation, and Chenopodiaceae are present. The wetland taxa indicate the presence of eutrophic carr and marsh vegetation. The values of Poaceae, Cyperaceae and fern spores are high, indicating an open landscape. At 5.60 m below surface, *Alnus* sp., *Urtica* sp. and *Salix* sp. show a peak.

In zone II (5.10 to 3.40 m below surface), the changes in the vegetation indicate increased water activity and/or an increase in the ground water level. *Quercus* sp. and *Ulmus* sp. become less dominant in the vegetation and are apparently replaced by *Fraxinus* sp. and shrubs (*Corylus* sp. and *Rhamnus cathartica*). The presence of *Fagus* sp. may reflect long-distance transport. The wetland vegetation changes strongly: Poaceae, Cyperaceae and fern spores (*Thelypteris palustris*-type) decrease, while *Alnus* sp. gradually rises and reaches a value of 740%, indicating local presence of alder carr.

In zone III (3.40 to 1.50 m below surface), the influence of running water and/or the ground water level decreases again. *Quercus* sp. increases, *Corylus* sp. and *Betula* sp. decrease, and *Fraxinus* sp. is replaced by *Ulmus* sp. *Alnus* sp. decreases while in contrast the *Thelypteris palustris*-type fern spores increase together with *Sphagnum* spores, indicating more mesotrophic conditions. The correspondence of the maximum of fern spores with a peak of *Pinus* pollen grains suggest that the local vegetation was relatively open at the end of this zone. In the dryland vegetation of zone IV (1.50 to 0.70 m below surface), *Quercus* sp. and *Betula* sp. rise, *Fagus* sp. probably appears in the extra-local vegetation, *Corylus* sp. decreases, and the diversity and importance of dryland herbs rises. In the wetland vegetation, *Salix* sp., Poaceae, Cyperaceae and Apiaceae rise while the fern spores decrease, and a variety of taxa appear, indicating that more eutrophic open marsh vegetation develops. The relative high values of *Salix* sp. indicate some water activity in the local or extra-local surroundings.

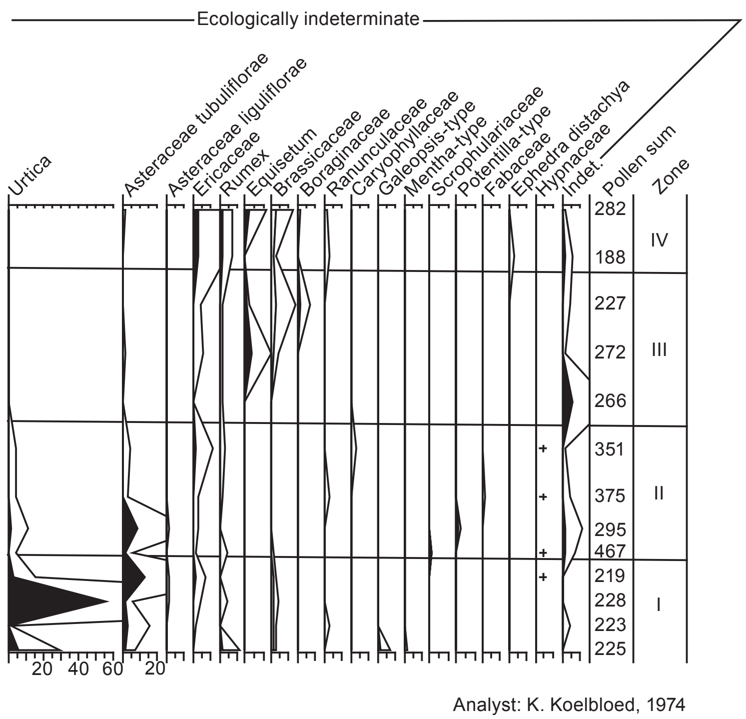

Figure 2.3 Bergambacht, pollen diagram based on an upland pollen sum, exaggeration 5 x (Stichting voor Bodemkartering), part 2.

2.2.4 Discussion of the pollen analysis

The age of the deposits is estimated to be Late Atlantic and Sub-Boreal. This estimation is based on comparison with a pollen diagram of Gouderak (unpublished data Stichting voor Bodemkartering), the presence of *Salvinia natans* that is usually found in Atlantic Rhine deposits (Zandstra 1966), the high values of *Fagus* sp. (in the upper part of the diagram) that was presumably absent in the region in the Atlantic, and the (apparent) absence of *Carpinus* sp. that was presumably present in the region from the later part of the Sub-Boreal onwards. This estimation is supported by a rough estimation of the age calculated by an interpolation model of the ground water levels based on depth, pointing to an age of *c.* 6100-2500 BC (Cohen 2005b). The pollen diagram demonstrates the presence of vegetation that is highly comparable with other sites in the central river area (deciduous woodland, alder carr and open wetland vegetation).

The presence of clay in zone II suggests that the presence of pollen grains of *Abies* sp. and *Fagus* sp. in the middle of the diagram reflects long distance transport by river water instead of (extra-) local presence. The peaks of *Picea* sp. and *Pinus* sp. closely correspond with each other, indicating that these taxa were not part of the (extra-) local vegetation either but were transported from other regions.

Potential evidence of human impact on the vegetation can be recognised in zone I and IV of the pollen diagram. The indications in zone I are the high values of Poaceae, Cyperaceae and *Thelypteris palustris*-type spores, the presence of *Persicaria lapathifolia*-type, *Rumex* sp., *Galeopsis*-type and *Mentha*-type at 5.90 m below surface. These indications are weak and could also reflect the natural vegetation along channels (Wolf *et al.* 2001). Therefore, anthropogenic influence is possibly present but not proved. Nevertheless, the pattern in the pollen diagram corresponds with signals of Mesolithic/Neolithic anthropogenic influence in other pollen diagrams sampled in the river area. In zone IV, the indications of human impact include the presence of *Plantago major*, *Plantago lanceolata*, Cerealia-type, *Rumex* sp., and high values of Poaceae and Cyperaceae. Although various taxa may have been part of the natural vegetation, the open vegetation and the presence of Cerealia-type pollen grains support the possibility of extra-local anthropogenic influence. Since the upper part of the diagram is estimated to be of Sub-Boreal age, the anthropogenic influence in zone IV does probably not reflect Early Neolithic occupation but instead Middle or Late Neolithic occupation.

2.2.5 Materials and methods of the macroremains analysis

The analysis of macroremains formed part of the archaeological prospection and was carried out in order to assess the preservation of botanical remains. The botanical macroremains were sampled with a core at a depth where the prehistoric surface of the inland dune was assumed to be present and where archaeological indicators were present in the sediment. The analysis consisted of 13 samples of 1 litre, sieved on a 0.25 mm sieve. The precise sample locations are unknown to the author. Reports containing the results of the research were kindly made available by BIAX *Consult* and ArcheoMedia (Van Beurden 2001; Dasselaar and De Koning 2005).

2.2.6 Results and discussion of the macroremains analysis

Table 2.1 shows the macroremains identifications from Bergambacht, which were all preserved in a waterlogged state. The results clearly demonstrate the nearby presence of typical eutrophic inland dune vegetation, consisting of a combination of dryland taxa and wetland taxa. On the one hand, *Tilia platyphyllos*, *Quercus* sp., *Corylus avellana*, *Cornus sanguinea*, *Prunus padus*, *Fraxinus excelsior*, *Rubus fruticosus*, *Rubus caesius* and Rosaceae indicate woodland and woodland edge vegetation of dry terrain, with open patches as suggested by several dryland herbs. On the other hand, alder carr, eutrophic water edges, *Carex* peat, and open water were probably nearby as well, as indicated by the presence of *Alnus* sp., *Berula erecta*, *Lythrum salicaria*, *Urtica dioica*, *Alisma* sp., *Persicaria hydropiper*, several *Carex* species, *Nuphar lutea* and *Nymphaea alba*. The diversity of taxa in samples can be explained by the potentially varied origin of the samples (different locations of the inland dune), possible variation in age, and the influence of several deposition processes.

The macroremains revealed a new species, *Barbarea stricta/vulgaris*, which has not been found at the other investigated sites in the river area dating to the Mesolithic and Neolithic. *Barbarea stricta* is characteristic of higher parts of *Salix* vegetation influenced by the tide and of marsh vegetation. In historical times, the leaves were eaten in times of scarcity for their vitamin C content (Weeda *et al.* 1987).

The macroremains do not give strong indications of anthropogenic influence on the vegetation. The macroremains assemblage does not contain carbonised seeds or fruits, cultivated plants are absent despite the age of the site, and the presence of herbs that indicate disturbance is restricted to some wetland taxa that can be part of the natural vegetation as well (*Persicaria hydropiper* and *Ranunculus repens*-type).

Woodland vegetation of dry terrain	*Carr and marsh vegetation*	*Open water vegetation*
Cornus sanguinea	Alnus sp.	Nuphar lutea
Corylus avellana	Humulus lupulus	Nymphaea alba
Fraxinus excelsior	Alisma sp.	
Prunus padus	Barbarea stricta/vulgaris	*Ecologically indeterminate*
Quercus sp.	Berula erecta	Apiaceae
Rosaceae	Caltha palustris	Brassicaceae
Rubus caesius	Carex elata	Cyperaceae
Rubus fruticosus	Carex elongata	Poaceae, epidermis
Tilia platyphyllos	Carex paniculata	Rumex sp.
Moehringia trinervia	Carex pseudocyperus	
Urtica dioica	Carex sp.	
	Filipendula ulmaria	
	Iris pseudacorus	
	Lycopus europaeus	
	Lythrum salicaria	
	Mentha sp.	
	Oenanthe aquatica	
	Persicaria hydropiper	
	Ranunculus acris	
	Ranunculus repens-type	
	Solanum dulcamara	
	Sparganium erectum	
	Valeriana officinalis	

Table 2.1 Bergambacht, macroremains, all waterlogged.

2.2.7 Discussion and conclusions

The results of Bergambacht are based on two sources of material, which were sampled independent from each other in the surroundings of Bergambacht. Detailed interpretation is not possible for a number of reasons; firstly, the pollen diagram is not dated, secondly, the distance between both sample locations is too large for direct correspondence, and thirdly, detailed information on the occupation of the several inland dunes at Bergambacht is not available at present.

In this study the pollen diagram of Bergambacht is a useful aid in the reconstruction of the natural vegetation in an area on the border of the central river area. The pollen diagram, dating to the Late Atlantic and Sub-Boreal period, shows that the vegetation at Bergambacht was similar to other sites in the river area dating to the same period. In the part of the pollen diagram that certainly corresponds with the period investigated in this study (5500-3400 BC), indications of anthropogenic influence are scarce. This scarcity can be related to the distance between the sample point and the nearest inland dune (1 km). In the upper part of the diagram, a clear anthropogenic signal is present but the age of the sediment or corresponding occupation is not precisely known.

The macroremains give information on the natural vegetation during an occupation period in the (Late) Neolithic. There are no strong indications of anthropogenic influence on the vegetation in the macroremains assemblage. A more detailed analysis of archaeobotanical material of the inland dune would probably lead to stronger signals of anthropogenic influence on the vegetation (Van Beurden 2001).

2.3 Pollen diagram of Goudriaan

2.3.1 Introduction

Goudriaan is located in the central river area (coordinates 120.900/ 433.250), 5 km northeast of Brandwijk-Kerkhof. A pollen core, published in Verbraeck (1970), was sampled in 1958 by the National Geological Survey in cooperation with the Stichting voor Bodemkartering at a location *c.* 2 km distance from several inland dunes. The sediment of the core consists of Holocene peat and clay deposits, while the sediment below the analysed spectra formed the transition to the Pleistocene subsurface. The main function of the pollen diagram in this study is to reconstruct the natural vegetation during the Middle and Late Neolithic. The diagram is not expected to be useful for the reconstruction of anthropogenic influence because of the distance between the sample point and the locations suitable for occupation. There is no detailed information available on occupation at the nearest inland dunes.

2.3.2 Material and methods

The pollen diagram of Goudriaan (Goudriaan I) is based on a report of the National Geological Survey (De Jong 1985), kindly made available by P. Cleveringa. The resulting reduced pollen diagram of the location Goudriaan was included in the information that is added to the geological map (Verbraeck 1970, 79). For the purpose of this study, the pollen diagram has been recalculated, based on an upland pollen sum that includes dryland trees, shrubs, herbs and spore plants. This pollen sum however results in a very low number of pollen grains included in the pollen sum, restricting the validity of the diagram. The presence of clay in the sediment indicates the possibility of secondary deposition of pollen grains.

The core was dated (see table 2.2). The diagram dates at least from *c.* 4350 to 2500 BC, corresponding with the Atlantic and the Sub-Boreal. The undated upper part may correspond with the Sub-Atlantic. Furthermore, the upper clay layer of the core was deposited after 1800 BC (Verbraeck 1970). The samples used for the dating were not sampled in the pollen core but instead in a second core that was collected at 1 metre distance from the pollen core. The depth of these samples is corrected for differences between the two cores.

depth (m -NAP)	lab code	age (yrs BP)	age (yrs cal BC, 2σ)	dated material
3.00-2.90	GrN-784	4095 ± 90	2900 (95.4%) 2460	wood
3.96-3.91	GrN-785	4650 ± 95	3650 (95.4%) 3100	wood peat
5.16-5.11	GrN-786	5340 ± 90	4340 (95.4%) 3980	wood and Phragmites peat

Table 2.2 Goudriaan, ^{14}C dates of the pollen core.

In the diagram as originally published by Verbraeck (1970), the ransition between the Atlantic and Sub-Boreal was drawn at 5.30 m -NAP, probably based on the fall of *Ulmus* sp., and the transition between the Sub-Boreal and Sub-Atlantic at 2.60 m -NAP. These zones were not applied after recalculation of the diagram.

2.3.3 Results

Figure 2.4 shows the pollen diagram from Goudriaan. The diagram can be divided into four biostratigraphical zones. Zone I (5.70 to 5.45 m -NAP) shows low values of *Quercus* sp. and high values of *Ulmus* sp. and *Corylus* sp. The presence of clay, low values of *Quercus* sp. and high values of *Ulmus* sp. indicate that the environment was relatively wet. The pollen of *Pinus* sp. probably does not reflect (extra-) local vegetation but instead regional pollen transported by river water.

Zone II (5.45 to 4.65 m -NAP) corresponds with the first date (4340-3980 BC) and is based on high values of *Quercus* sp. and low values of *Pinus* sp. and *Corylus* sp. The curves of *Quercus* sp., *Betula* sp. and *Rhamnus cathartica* increase, indicating the development of dryland vegetation in the extra-local area. In the wetland vegetation, *Alnus* sp., *Salix* sp., Typhaceae and Poaceae are important elements in the lower part of the zone, corresponding with the peaty sediment. The peak of *Salix* sp. indicates dynamic water activity.

Zone III (4.65 to 3.55 m -NAP) corresponds with the second date (3650-3100 BC) and is based on high values of *Pinus* sp. and *Corylus* sp. and a strong decrease in *Quercus* sp. The high *Pinus* values are probably a result of the low pollen sum; it is considered as unlikely that they indicate the local presence of *Pinus* sp. The apparent absence of *Ulmus* sp. and *Betula* sp. is probably related to the high values of *Pinus* sp. and the low pollen sum. In the wetland vegetation, alder carr was present. In the upper part of the zone, a clay layer is present, correlating with strong changes in the pollen diagram. Firstly, the variety of dryland herbs increases and Cerealia-type is present, indicating human activity. Secondly, *Salix* sp. develops in the wetland vegetation, combined with peaks of Poaceae, Apiaceae and Brassicaceae. These changes may indicate anthropogenic influence in the extra-local area. Alternatively, it may also concern secondary deposition of pollen grains and disturbance of the wetland vegetation due to water activity, as the sediment consists of clay.

Zone IV (3.55 to 2.40 m -NAP) corresponds with the third date (2900-2460 BC) and is based on low values of *Pinus* sp., decreased values of *Ulmus* sp. and increased values of *Betula* sp. *Quercus* sp. rises, again combined with *Rhamnus cathartica*, while *Corylus* sp. decreases. The changes indicate a relative decrease in the ground water level or the flooding frequency. The dryland herb taxa contain two anthropogenic indicators: *Fallopia convolvulus* and *Plantago lanceolata*. From this zone onwards, *Fagus* sp. appears regularly, which suggests its arrival in the region, although its presence in the diagram is related to the presence of clay. The indicators of open water indicate a water depth of maximal 2 metres depth, and the presence of this open water apparently resulted in a major reduction of the *Alnus* sp. and *Salix* sp. vegetation.

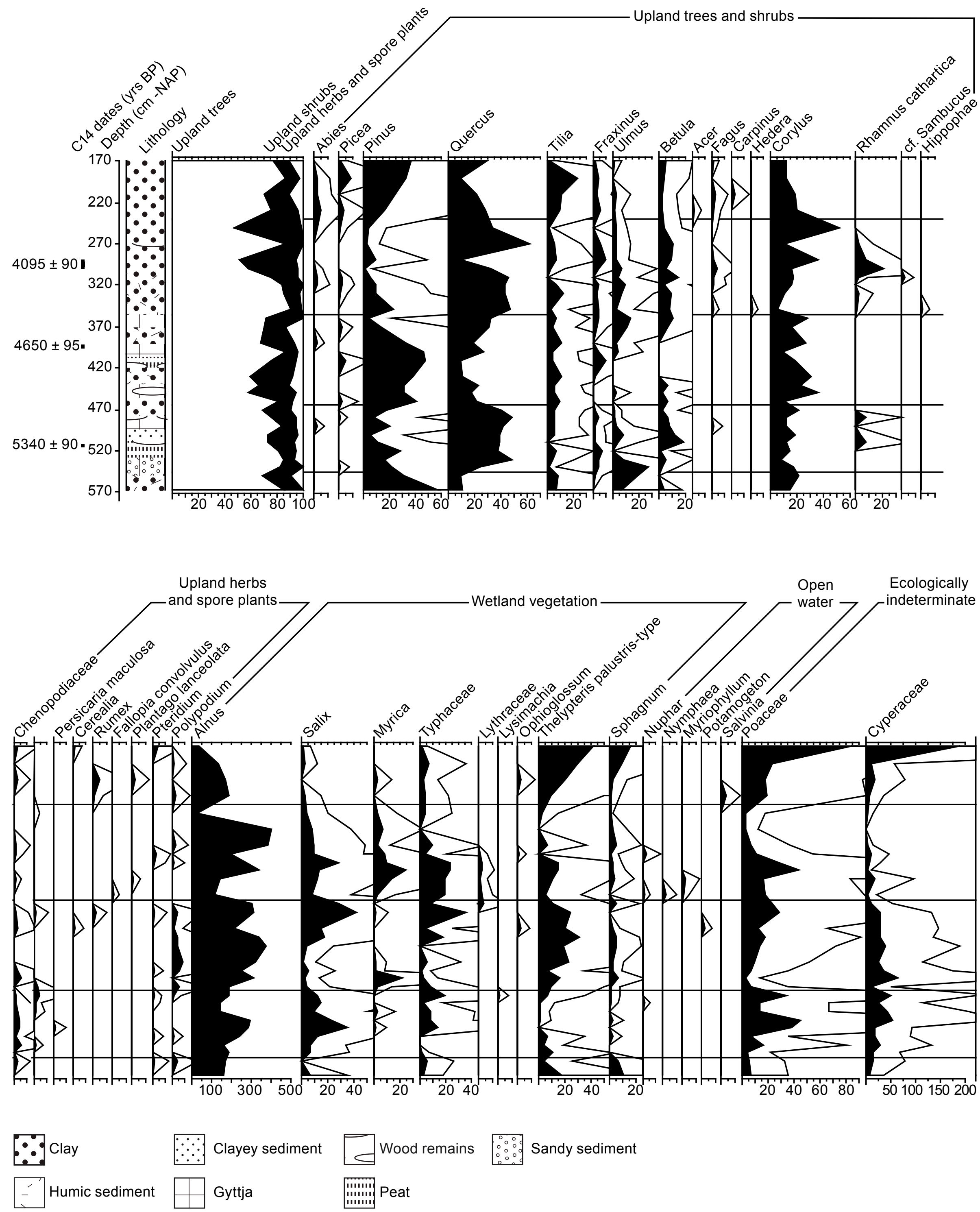

Figure 2.4 part 1.

Zone V (2.40 to 1.70 m -NAP) shows changes that are strongly related to the presence of clay, similar to the changes in the end of the previous zone. The taxa *Pinus* sp. and *Tilia* sp. increase that can probably be attributed to inter-regional pollen transport by river water, while *Quercus* sp. and *Corylus* sp. decrease. Poaceae are constantly present with moderately high values while the curve of *Thelypteris palustris*-type increases strongly, similar to the curve of *Pinus* sp. The high values of Poaceae and Cyperaceae in the upper part of the diagram in combination with the presence of Cerealia-type pollen may indicate Bronze Age or Iron Age farming activities.

2.3.4 Conclusions

The changes in the pollen diagram of Goudriaan are closely related to changes of the sediment, indicating influence of water activity and possible secondary deposition. Zones I, II and III correspond with the Early and Middle Neolithic (the period of the Swifterbant culture and Hazendonk group). In general, the diagram demonstrates that the natural vegetation at Goudriaan, located in the eastern part of the central river area, is highly comparable with the vegetation of the central part of the central river area during the Middle Neolithic, also after the Atlantic. The diagram contains some indications of anthropogenic influence on the vegetation, but the distance to the inland dunes, the possibility of secondary deposition and the low pollen sum hamper further interpretation of the data.

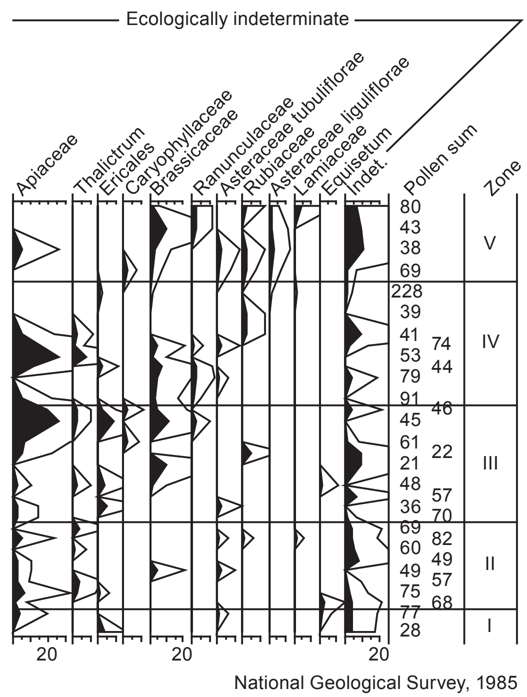

Figure 2.4. Goudriaan, pollen diagram based on an upland pollen sum, exaggeration 5 x (National Geological Survey), part 2.

2.4 Zijdeweg, Rechthoeksdonk and Meerdonk

The inland dunes Zijdeweg, Rechtshoekdonk and Meerdonk were investigated by M. Verbruggen in 1990, 1989 and 1993 respectively as part of a research project based on prospection of Late Glacial inland dunes for Neolithic occupation (Verbruggen in prep.). Information on their occupation is based on analysis of archaeological refuse obtained by coring. The discussion below is based on data that were kindly made available by M. Verbruggen.

The dune Zijdeweg is located in the northwestern part of the central river area, near the Schoonenburgsche heuvel (coordinates 109.850/433.750). Two occupation periods are dated to *c.* 5220-5100 and 3890-3730 BC (Verbruggen in prep.), based on ^{14}C dates and the ground water level curve (see Verbruggen 1992). Their age and location suggest that occupation corresponds with an initial and late phase of the Swifterbant culture.

An archaeobotanical sample of Zijdeweg obtained by coring was investigated for the presence of botanical macroremains by W.J. Kuijper. The sample was collected at 7.36 to 6.86 m -NAP and corresponds with the occupation period at 5220-5100 BC. The extent of the refuse layer (fossil anthropogenic horizon) representing this occupation period is relatively restricted compared with the refuse layers of other dunes. Nevertheless, the refuse layer was relatively rich in charcoal and bone remains. The sample consisted of peat; the reported volume is *c.* 1 litre.

Table 2.3 shows the results of the macroremains analysis of Zijdeweg. This result is highly similar to the results of archaeobotanical investigations on occupation from the same period at other inland dunes. The results indicate the presence of woodland of dry terrain (including *Tilia* sp.), alder carr, eutrophic marsh vegetation and open water, although accurate representativity is not assured since it only concerns a single sample. The sample probably represents a broad time range, and therefore, contemporaneous presence of all these vegetation types

taxon	N	taxon	N
Woodland vegetation of dry terrain		*Open water vegetation*	
Corylus avellana	+	Nuphar lutea	2
Tilia sp.	2	Nymphaea alba	2
Galeopsis-type	1	Potamogeton sp.	2
		Trapa natans, fragments of spines	26
Carr and marsh vegetation		Trapa natans, fruits	2 c
Alnus sp.	1		
Alnus sp., cones	3	*Ecologically indeterminate*	
Carex sp.	+	Ranunculus repens-type	2
Schoenoplectus lacustris/tabernaemontani	++	Silene sp.	2
Solanum dulcamara	2		
Sparganium erectum	1	*Varia*	
Persicaria minor	+	Fish remains	+ c

c = carbonised

+ = few (1-9)

++ = several tens (10-49)

Table 2.3 Zijdeweg (5220-5100 BC), macroremains, sample volume *c.* 1 litre.

is not demonstrated. Interestingly, the sample contained considerable numbers of carbonised remains of fruits of *Trapa natans*. This is the only species found in a carbonised state in the sample.

The carbonised fruits of *Trapa natans* are probably indicative of handling by people of this plant. The sample suggests that the site was very rich in waterlogged and carbonised fruits of *Trapa natans*, and the sample can be considered as being indicative of the presence of concentrations of carbonised remains of *T. natans*. There are several arguments that support this hypothesis. The location of collection was very rich in charcoal and probably represents an archaeological site. During investigation of the site by coring, fruits of *T. natans* were repeatedly recognised in the field, while such frequent presence of *T. natans* is not known from any of the other sites that were investigated during the same research project (pers. comm. Verbruggen 2006). It is unlikely that the charcoal represented reworked charcoal since it is mainly embedded in peat that is poor in clay. As a result, intentional collection of *T. natans* by people is likely. However, the absence of more detailed investigation of the site restricts the possibilities for interpretation, and the precise evidence of collection remains to be confirmed by future research.

The inland dune Rechthoeksdonk (Over Slingeland II) is located in the eastern part of the central river area (coordinates 123.000/432.800). Occupation is dated to *c.* 4240-3980 BC (Verbruggen in prep.). The age and location suggest that occupation corresponds with the middle phase of the Swifterbant culture. The refuse layer contained large quantities of charcoal and fish remains, and also pottery. A sample collected with a core at 4.60 to 4.20 m -NAP (volume unknown) was investigated for the presence of macroremains, which were identified by W.J. Kuijper and C.C. Bakels in 2007. The sample contained a carbonised grain of *Triticum dicoccon*, a carbonised grain of *Hordeum vulgare* var. *nudum* and a carbonised fruit of *Galium aparin*e.

The site Meerdonk is located on an inland dune in the central river area near the site Zijdeweg (coordinates 110/433). Occupation periods are dated to *c.* 4330-4210 and 4030-3910 BC (Verbruggen in prep.). Their age and location suggests that occupation corresponds with the Swifterbant culture. The spatial distribution and thickness of the archaeological refuse layer suggest that this dune was intensively occupied during the second occupation period.

An archaeobotanical sample of Meerdonk obtained by coring was investigated for the presence of botanical macroremains by W.J. Kuijper. The sample was collected at 5.60 to 5.25 m -NAP, probably at several metres distance from the edge of the dune, and corresponds with the occupation period at 4030-3910 BC. The sample consisted of peaty sediment; the volume is reported as *c.* 0.5 litres. The presence of small seeds suggests that the sample was sieved on a 0.25 mm sieve.

Table 2.4 shows the macroremains from Meerdonk. The sample shows a large variation of taxa and indicates the presence of woodland of dry terrain with open patches, carr, marsh vegetation and open water. However, the sample probably represents a broad time range, and contemporaneous presence of all these vegetation types is not demonstrated. The botanical remains give several indications of human impact at the dune. Firstly, the ruderals may indicate human impact on the local vegetation. Secondly, the presence of carbonised macroremains of *Corylus avellana* and *Malus sylvestris* indicate human presence (possibly during autumn although storage cannot be excluded). Thirdly, carbonised remains of the crop plants *Triticum dicoccon* (a grain) and *Hordeum vulgare* (an internodium) strongly support human presence. As it concerns an internodium of barley only and no grains, it is not possible to distinguish between naked barley or hulled barley. Comparison with comparable sites of dating to the same period nevertheless suggests that it concerns naked barley (*Hordeum vulgare* var. *nudum*). The presence of charcoal, bone and fish remains and quarts support the anthropogenic context of the sample. The identifications of the crop plants after analysis of only a single sample from both Rechthoeksdonk and Meerdonk support the importance of these taxa in the subsistence of the Swifterbant culture. A remarkable find in the assemblage is the fruit of *Nepeta cataria*, a species indicative of forb vegetation on a soil rich in lime (calcium). The oldest finds of the Netherlands date to the Roman period (RADAR 2005). Other indicators of lime are usually scarce at the inland dunes in the Late Mesolithic and later.

taxon	N	taxon	N
Woodland vegetation of dry terrain		*Carr and marsh vegetation (cont.)*	
Corylus avellana	+	Lythrum salicaria	++++
Corylus avellana	+ c	Phragmites australis	+
Crataegus monogyna	1	Phragmites australis, stem	
Malus sylvestris	1	fragments	1
Malus sylvestris	1 c	Rumex hydrolapathum	1
Rhamnus cathartica	1	Schoenoplectus lacustris	2
Galeopsis bifida-type	+	Scrophularia sp.	1
Urtica dioica	+++	Typha angustifolia/latifolia	+
Ruderals and pioneers of dry terrain		*Wetland pioneer vegetation*	
Chenopodium album	+++	Bidens cf. cernua	1
Nepeta cataria	1	Persicaria hydropiper	1
Persicaria lapathifolia	++		
Persicaria maculosa	+	*Open water vegetation*	
Solanum nigrum	1	Callitriche sp.	++
Stellaria media	+++	Chara sp.	+
		Elatine hydropiper	+++
Crop plants		Elatine triandra	+
Hordeum vulgare, internodia	1 c	Nymphaea alba	1
Triticum dicoccon	1 c	Salvinia sp.	+
Carr and marsh vegetation		*Ecologically indeterminate*	
Alnus glutinosa	++	Poacea, small	+
Alnus glutinosa, cones	+	Veronica beccabunga-type	+
Alnus glutinosa, bud scales	+		
Salix sp., buds	1	*Varia*	
Alisma plantago-aquatica	+	Charcoal remains	+
Carex cf. acutiformis	1	Bone and fish remains	+
Epilobium hirsutum-type	1	Quartz	+
Eupatorium cannabinum	1	Mosses	+
Juncus sp.	+++		

c = carbonised
\+ = few (1-9)
++ = several tens (10-49)
+++ = many tens (50-99)
++++ = several hundreds (100-499)

Table 2.4 Meerdonk (4030-3910 BC), macroremains, sample volume *c.* 0.5 litres.

2.5 Hardinxveld-Giessendam Polderweg and Hardinxveld-Giessendam De Bruin

The discussion of Hardinxveld-Giessendam Polderweg and De Bruin is primarily based on Louwe Kooijmans (2001a, b, 2003). The archaeobotany is discussed in appendix I. The appendices mentioned in this chapter preferably should be read first for an optimal understanding of the results presented in this chapter. Occupation at Polderweg took place during several phases between 5500-5000 BC, while De Bruin was occupied between 5500 and 4500 BC.[6] The distance between the sites Hardinxveld-Giessendam Polderweg and De Bruin is 1 km. The sites reflect the early stages of the neolithisation process of the Dutch wetlands. The early stage is purely Final Mesolithic. Pottery is present from *c.* 5000 BC onwards at both sites. During the last occupation phase at De Bruin, bones of domestic animals were present (cattle, pig, goat and sheep). Crop plants are fully absent at both sites, as demonstrated by an extensive sampling program directed on the discovery of cereal remains. Several finds indicate relatively strong contact with communities in the south (southern Netherlands and Belgium) as well as some contact with the northern part of the Netherlands. The subsistence of both sites can be characterised as a broad-spectrum economy based on hunting, gathering, fishing and fowling. The site Polderweg is interpreted as a winter base camp during occupation phase 1, although continuous winter occupation is not assured. For the other phases of Polderweg, there is not enough information to make strong conclusions about seasonality. The site De Bruin is interpreted as a winter base camp with a shift in function through time towards an extraction camp in various seasons.

At both sites, the dryland vegetation consisted of deciduous woodland comprising *Tilia* sp., *Quercus* sp., *Ulmus* sp., *Fraxinus excelsior*, *Corylus avellana*, *Rhamnus cathartica*, *Viburnum opulus*, *Cornus sanguinea* and possibly *Humulus lupulus* (this last species might have grown in the alder vegetation as well). The characteristics of the wood and charcoal remains, the fungi and the mosses indicate that the woodland was generally humid, dense and of considerable age. The wetland vegetation at both sites consisted of *Alnus* carr vegetation, forb vegetation, marsh vegetation and lake vegetation (including submerged and floating water plants). The wetland environment was very eutrophic with only minor mesotrophic patches. The dune gradually submerged due to the gradual rise of the water level, resulting in a decrease in the woodland vegetation of dry terrain and an increase in wetland vegetation.

Indications of anthropogenic influence on the vegetation consists of scarce signals of human impact in the pollen diagrams, presence of ruderals, finds of carbonised macroremains, and presence of wooden artefacts, possibly worked wood remains and charcoal. The pollen diagrams hardly show indications of human impact. For some cores this could be related to the distance to the inland dune surface (Polderweg: 4 and 26 metres, De Bruin: up to 8 metres) and the distance to the refuse layer (Polderweg: 40 metres, De Bruin: 0 metres), but a series of pollen boxes sampled close to the dune De Bruin (within the excavation trench) indicates that human impact indeed was very limited. Only one clear signal can be distinguished, related to a specific type of human activity directly next to the sampling location (De Bruin phase 2). For the remaining fluctuations in the pollen diagrams, it is difficult to exclude that natural processes of disturbance, such as tree falls or activity of wild animals, caused the slight changes in the vegetation. It is possible to observe an increase in the secondary shrub vegetation (*Viburnum opulus*, *Rhamnus cathartica*, *Cornus sanguinea*-type and *Sambucus nigra*-type), but the increase is mostly gradual and/or not supported by other anthropogenic indicators. There are furthermore no indications of recovery of the vegetation after any of the occupation phases. It must therefore be concluded that the strength of human impact was restricted and relatively continuous. It is not possible to reconstruct a relationship between occupation intensity and the observed evidence of human impact.

Macroremains of several taxa were found in a carbonised state (see appendix I); the overall number of taxa (N = 19) is however small in view of the long period of occupation and the scale of the excavations.

6 Recalculation of the ^{14}C dates of Polderweg and De Bruin resulted in the new conclusion that Polderweg was occupied between 5430 ± 90 and 5069 ± 140 cal BC, and De Bruin between 5230 ± 150 and 4480 ± 160 cal BC (Mol and Van Zijverden 2007). See the notes in appendix I for further details.

The assemblage of carbonised macroremains contains potential food plants and marsh taxa but hardly any ruderals. The scarcity of ruderals in a carbonised state corresponds with the absence of crop plants and crop processing activities.

The assemblages of wood and charcoal indicate exploitation of both dryland and wetland vegetation in the near surroundings of the inland dunes. *Alnus* sp., *Quercus* sp. and *Fraxinus* sp. are the dominant taxa in the assemblages of unworked wood and charcoal remains. At both sites, the variety of taxa in the wood and charcoal assemblages is high. Most taxa could have been collected at the inland dunes themselves, but there are also some indications of import of wood.[7] Characteristics of the charcoal indicate use of both old wood and humid, possibly fresh wood at both sites. The taxa used for artefacts indicate that people practised selective use of wood based on the quality of the wood and the function of artefacts.

2.6 Brandwijk-Kerkhof

The site Brandwijk-Kerkhof was occupied from *c.* 4600 to 3550 BC by people of the Swifterbant culture. The site fills the later end of the chronological gap between the mainly non-agricultural sites of Hardinxveld-Giessendam and the semi-agricultural site of the Hazendonk. An excavation trench of 3 x 10 metres at the southern side of the dune was investigated, and several refuse layers were attested. The earliest layer of Brandwijk-Kerkhof (layer 30) contains a few pottery sherds and one bone of goat/sheep, while the later layers contain more bones of various domestic animals and additionally crop plants as well (layers 50 and 60; Raemaekers 1999). The excavation is not analysed and published completely yet. The site is interpreted as a special activity camp, occupied at least during summer and winter.

The archaeobotanical analysis consisted of the analysis of pollen and macroremains from four cores, and the analysis of macroremains, wood and charcoal remains from the excavation pit (see Out 2008a and appendix II for more information). The four cores were sampled at the northern side of the dune at a distance of 1, 5, 10 and 20 metres distance from the foot of the dune. The analysis of the cores has demonstrated the presence of deciduous woodland of dry terrain, woodland edge vegetation, alder carr, eutrophic marsh vegetation and the presence of open water. The dryland vegetation on the slopes of the dune submerged due to the gradual rise of the ground water. It is difficult to distinguish human impact accurately from natural processes of disturbance that may have played a role as well. Human impact was maximal during layer 50 and/or 60 (*c.* 4000-3800 BC). Anthropogenic influence on the vegetation resulted in restricted clearance of *Tilia* sp., *Quercus* sp. and *Alnus glutinosa*. The presence of shrubs and herbs furthermore increased, indicating disturbance of the vegetation and development of open patches. After occupation, the vegetation recovered and woodland of dry terrain remained present on the top of the dune during occupation. The strength of the signal of anthropogenic influence on the dryland vegetation did not decrease over a distance of 20 metres from the dune (Out 2008a).

The analysis of macroremains, wood and charcoal included samples of four refuse layers that correspond with different occupation periods. These results confirmed the results of the cores. Crop plants were present from 4220-3940 BC onwards (*Triticum dicoccon*, *Hordeum vulgare* var. *nudum* and *Papaver somniferum* ssp. *setigerum*). In the data set currently available for the central river area, the introduction of crop plants at Brandwijk-Kerkhof represents the introduction of crop plants in the central river area. It is argued that crop plants were absent before 4370 BC. This statement is partly based on the evidence of De Bruin as the evidence of absence of crop plants before 4370 BC at Brandwijk-Kerkhof is restricted due to the restricted extent and sampling of relevant refuse layers. Large-scale crop cultivation at Brandwijk-Kerkhof is unlikely.

7 This imported wood may have been collected outside the exploitation area, while collection within the exploitation area cannot be excluded. Import in this manuscript, implying collection outside the exploitation area of a site, refers to transport over distances that are larger than 5 to 10 km, and does not necessarily refer to trade or transport over long distances of hundreds of km.

Instead small-scale crop cultivation may have occurred, or import of crop plants. Carbonised remains of several taxa included potential food plants, use plants and arable weeds. The carbonised remains indicate occupation between July and November while occupation during the winter is also possible. Wood remains additionally indicate spring/summer and probably autumn occupation for layer 50. The wood assemblage was dominated by *Alnus* sp., *Quercus* sp. and *Corylus avellana*. The charcoal assemblage indicates dominance of *Alnus* sp. and *Corylus avellana* and indicates the use of brushwood (see appendix II).

2.7 Hazendonk

The archaeology and new archaeobotanical results of the Hazendonk are discussed in detail in appendix III and compared with earlier publications in appendix IV (see also Out 2008d). The Hazendonk was occupied and visited between *c.* 4000-2500 BC by people of the Swifterbant culture, Hazendonk group, Vlaardingen group and Bell Beaker culture. Low percentages of domestic animals and crop plants were present in most investigated refuse layers. Various archaeological publications are available but the results of the excavation have not been published completely yet.

The reconstruction of the natural vegetation resulting from the new archaeobotanical data generally corresponds with earlier publications, although there are subtle differences. The new data give a more precise reconstruction of the dryland vegetation since the sample locations were near the dune. The data demonstrate the presence of *Tilia*/*Quercus* woodland of the inland dune, and alder carr, eutrophic marshes and open water in the lower parts of the landscape. The *Tilia*/*Quercus* woodland gradually submerged due to the gradual rise of the ground water level. After occupation phase Vlaardingen 1b, running water was present at the southeastern side of the dune.

The pollen diagrams as well as the macroremains diagrams reflect human impact during the occupation phases. Subtle differences in human impact can be observed between the various occupation phases. People cleared dryland and carr vegetation, affecting *Tilia* sp., *Quercus* sp. and *Alnus glutinosa*, and also other taxa, as suggested by the wood assemblage. These clearance activities as well as grazing by domestic animals resulted in an increase in shrubs and herbs, pointing to more open vegetation. The strength of human impact remained however of a small-scale during all phases. Occupation phases that are characterized by a large amount of archaeological refuse result in a strong signal of human impact in the pollen diagrams.

The analysis of several cores allowed comparison of the strength of human impact at increasing distance from the dune. The pollen diagrams from the slope of the dune show a decrease in the signal of human impact on the dryland vegetation over a distance of 4 metres (unlike the results of Brandwijk-Kerkhof). This result is obtained for an Early Neolithic and a Late Neolithic occupation phase and is confirmed by the comparison with evidence of human impact in other diagrams from adjacent locations (Louwe Kooijmans 1974; Van der Wiel 1982). The decrease in the signal of human impact over a distance of only a few meters can be explained by the restricted scale of human impact in combination with the presence of dense vegetation on the slope of the dune. The signal of human impact was stronger at locations where much archaeological remains were found, demonstrating that distance to the location of human activity plays an important role in the registration of human impact. Overall, the new results demonstrate that it can be worthwhile to analyse on-site pollen and macroremains diagrams from refuse layers from excavations.

The crop plants found at the Hazendonk are *Triticum dicoccon* and *Hordeum vulgare* var. *nudum*. Similar to Brandwijk-Kerkhof, large-scale local arable farming is unlikely, as indicated by the pollen diagrams. Instead, people may have practised small-scale arable farming or may have imported cereals in the ear from other regions. The data of phase Hazendonk 1 are more informative than the data from other phases, pointing to import of crop plants during that phase.

2.8 Synthesis central river area

2.8.1 Occupation and neolithisation

During the period 5500-3400 BC, the landscape in the central river area was dominated by wetlands, influenced by the gradual rise of ground water level and an anastomosing river system. The complexes of inland dunes formed small dryland elements in the landscape, many of which were occupied during at least a part of the year in the Late Mesolithic and Neolithic (Verbruggen 1992). From other dryland patches in the river area (see paragraph 2.1.3) no major archaeological sites dating to the period studied are known. The main sites in the region that are investigated on a considerable scale are the dunes of Hardinxveld-Giessendam Polderweg, Hardinxveld-Giessendam Polderweg De Bruin, Brandwijk-Kerkhof and the Hazendonk. The distribution of waste at the sites indicates that people performed activities at the edge and on the slopes of the dune, while occupation may also have occurred on their tops. These are, however, generally disturbed by erosion and/or by modern human activity and are not so informative anymore. The archaeological remains are mainly collected from refuse layers, formed by dumping activities and colluviation processes, which caused transport of material from the higher parts of the dune downslope. Figure 2.5 shows an overview of the occupation periods at the main sites, and the distinction of cultural groups and phases. Occupation at these sites corresponds with the Late Mesolithic, the early and middle phase of the Swifterbant culture, and the Hazendonk group. At the Hazendonk, occupation continued after the period studied.

The studied sites represent the transition from a Late Mesolithic to a Middle Neolithic since they show the introduction of pottery at *c.* 5000 BC, of domestic animals between 4700 and 4450 BC and finally

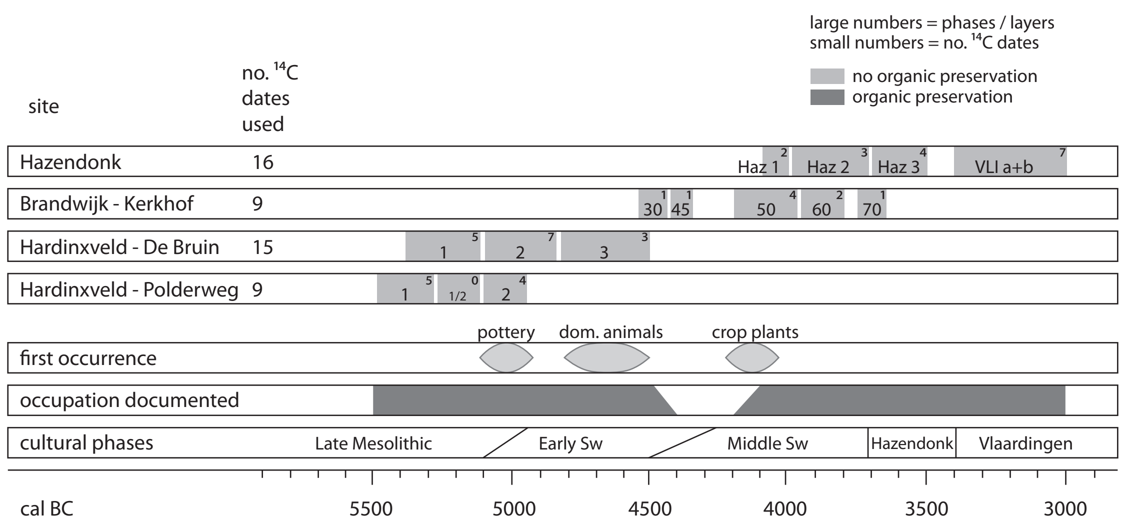

Figure 2.5 The central river area, main sites, overview of the occupation periods and the introduction of pottery, domestic animals and crop plants. The various occupation periods of most sites are not precisely dated and may have been shorter than suggested in the figure. The figure is based on a new interpretation of dates (L.P. Louwe Kooijmans 2009). SW = Swifterbant culture.

of crop plants sometime between 4500 and 4000 BC. The data of De Bruin and the early layers of Brandwijk-Kerkhof indicate that crop plants were absent before 4370 BC (see appendices I and II). The extent of the refuse layers and the number of samples representing the period 4470-4370 BC, found at Brandwijk-Kerkhof only, are however restricted and the interpretation on the absence of crop plants needs confirmation by data from other sites. For the period 4370-4220 BC there are no data available on the presence of crop plants since there are no sites excavated dating to this period. The data of Brandwijk-Kerkhof indicate that crop plants were present from 4220-3940 BC onwards, which is supported by the cereal finds from the Hazendonk (*c.* 4000 BC), Rechthoeksdonk and Meerdonk.

The subsistence of the Hardinxveld-Giessendam sites was based on hunting, fishing, fowling and gathering. At Hardinxveld-Giessendam De Bruin bones of domestic animals were found but these are assumed to represent import of parts of animals instead of living animals, with possible exception of pig. The subsistence of the communities using the sites of Brandwijk-Kerkhof and the Hazendonk was based on a combination of hunting, fishing, fowling, gathering, animal husbandry and crop cultivation.

The site Polderweg is interpreted as a winter base camp during occupation phase 1. This seasonal winter occupation and the 5500-5300 BC date make local crop cultivation an unlikely option. The site De Bruin is interpreted as a base camp with a shifting function from a winter base camp to an extraction camp during various seasons. The site Brandwijk-Kerkhof was probably used continuously as a hunting camp in various seasons (Raemaekers 1999). This interpretation makes local crop cultivation unlikely. However, there are indications of a possible shift in site function during the later phases (see appendix II), which may have enabled local crop cultivation during the late phases (phase 50 and 60). The Hazendonk may reperesent a supportive special activity site that was occasionally occupied more permanently. There are zoological indications of occupation during all seasons for almost all phases. A site function as a special activity site makes local cultivation unlikely. An interpretation of the site as a more permanent occupatied base camp would enable local cultivation.

The pottery and flint of the central river area is in the first place characteristic of the Swifterbant culture and the subsequent Hazendonk group. Finds indicative of long-distance relations mainly point to contact to the southeast and south (South-Limburg, Belgium), while there are minor indications of contact with the north (Utrechtse Heuvelrug). There are indications of contact with the LBK, Blicquy group, Rössen culture and Michelsberg culture. It is not known how the contact with Neolithic communities influenced the knowledge about agriculture before the introduction of domesticates. The central river area is bordered to the south by the Pleistocene sand soils of Noord-Brabant. The distance to the sand soils was *c.* 5-10 km at 5500 BC and 10-15 km at 4500 BC (Louwe Kooijmans 2001b, 519). People of the Swifterbant culture and Hazendonk group may have occupied these regions, as is suggested by several sites and finds of single artefacts. However, data on occupation of these regions are too scarce to reconstruct the occupation history of the Pleistocene soils in detail. Information on Neolithic communities (in material sense) on the sandy soils of Belgium and the southern Netherlands is poor, and restricted to some stray finds of implements and pottery. An exception is the Limburg Meuse valley, where an expansion of Michelsberg has been documented, but with only very scarce information on agriculture. So the time of introduction of cereals and domestic animals is factually unknown in this region, and the central river area dates should be considered as a *terminus ante quem* in view of the specific role of the sites in a settlement system, which may have covered both the wetlands and the sand.

For the archaeobotanical discussion, occupation in the central river area is divided into two phases, based on the presence of crop plants. In the first phase, corresponding with occupation at Polderweg and De Bruin and with the early phases of Brandwijk-Kerkhof (layer 30 and 45, 4610-4370 BC), remains of crop plants were absent. In the second phase, corresponding with the late phases of Brandwijk-Kerkhof (layers 50 and 60, 4220-3820 BC), the Swifterbant phases at the Hazendonk (phases Hazendonk 1 and 2, 4000-3800 BC) and the phase of the Hazendonk group at the Hazendonk (phase Hazendonk 3, 3670-3610 BC), crop plants were present. The data of the Late Neolithic phases of the Hazendonk are only discussed when relevant.

2.8.2 Reconstruction of the natural vegetation

In the central river area, the differences of the height of the Pleistocene subsurface and the activity of the river system resulted in a variety of ecotopes[8] and plant communities, structured in mosaic-like patterns. The natural vegetation of the region was relatively similar at the various research locations. On dry terrain, deciduous lime/oak woodland was present, accompanied by woodland edge vegetation and hardwood alluvial woodland vegetation. Shrubs and few herbs were present in the understory of the deciduous woodland and on the slopes of dunes. The wetland vegetation was the dominant element of the landscape, comprising softwood alluvial woodland vegetation, alder carr, marsh and river bank vegetation, and vegetation of open water of varying depths. The environment was mainly eutrophic with exception of some slightly mesotrophic patches, related to the presence of seepage water and decreased influence of the ground water. Several sources demonstrate the presence of taxa that indicate a high water quality (clear water that is poor in nutrients).

It is assumed that the unworked wood and charcoal (see tables 2.5 and 2.6) represent the main elements of the natural vegetation of the dunes, the slopes of the dunes and the surrounding wetlands, although there are exceptions. The assumption that also the charcoal primarily represents the natural vegetation is based on the principle of least effort (*e.g.* Shackleton and Prins 1992). It is furthermore assumed that most tree and shrub taxa that are found in two or more botanical material groups (pollen, seeds, wood and/or charcoal) were probably present in the (extra-) local vegetation in the central river area. Combining both assumptions, the local presence of many woody taxa at and around the dunes is likely. There are however some trees and shrubs of which the local presence is questionable since they are poorly represented in the data set of the dunes in the central river area: *Acer campestre*, *Betula* sp., *Euonymus europaeus*, *Ilex aquifolium*, *Malus sylvestris*, *Prunus avium, Prunus padus*, *Sorbus aucuparia* and *Taxus baccata*. Comparative analysis of all archaeobotanical sources of the region indicates that *Prunus avium* was probably not present in the central river area during the studied period (see chapter 7). *Taxus baccata* may have become part of the vegetation during the Neolithic but details are unknown yet (see chapter 7). *Acer campestre*, *Betula* sp., *Euonymus europaeus*, *Malus sylvestris* and *Prunus padus* were probably part of the local vegetation[9], at least at some of the studied sites. Local presence remains unclear for *Ilex aquifolium* and *Sorbus aucuparia*.

In contrast to the dryland vegetation of the dunes, the vegetation of natural levees and channel belts is not precisely known. Low channel belts and especially levees would have been flooded more often, resulting in regular moist to wet conditions and deposition of clay. Van der Woude (1983) suggests the presence of *Quercus* sp., *Ulmus* sp., *Fraxinus excelsior*, *Corylus avellana* and *Alnus glutinosa* on channel belts and the presence of *Ulmus* sp., *Corylus avellana* and *Alnus glutinosa* on natural levees, together with wetland vegetation at the lower parts. Stortelder *et al.* (1998) characterize natural levees by presence of *Fraxinus excelsior*, *Quercus robur*, *Ulmus* sp. and *Crataegus monogyna*. This suggests that vegetation on natural levees and channel belts was rather similar to the vegetation of the dunes, with the exception of *Tilia* sp. However, Hofstede *et al.* (1989) and De Klerk *et al.* (1997) suggest that *Tilia* sp. was also part of the natural vegetation of levees.

8 Ecotopes: smallest spatially homogeneous unit of the landscape, characterised by homogeneous vegetation and the accompanying abiotic conditions (Berendsen 1997b).

9 Unworked wood of *Acer* sp. has been found at the Hazendonk, and macroremains of *Acer* sp. have been found at De Bruin and the Hazendonk (*A. campestre*). Uncarbonised macroremains of *Prunus padus* have been found at De Bruin and the Hazendonk. Pollen of *Euonymus* sp. has been found at the Hazendonk. *Malus sylvestris* was probably present at the Hazendonk and possibly at Brandwijk-Kerkhof, but not at Hardinxveld-Giessendam.

taxon / site	Polderweg	De Bruin	Hazendonk	Brandwijk-Kerkhof	dominance
Acer sp.	+	-	+	-	
Alnus glutinosa	+	+	+	+	1
Betula sp.	-	+	-	-	
Cornus sanguinea	+	+	+	+	
Corylus avellana	+	+	+	+	2
Euonymus europaeus	-	+	-	-	
Fraxinus excelsior	+	+	+	+	2
Pomoideae	+	+	+	+	
Prunus padus	+	-	-	-	
Quercus sp.	+	+	+	+	2
cf. Rhamnus frangula	-	+	-	-	
Salix sp.	+	+	-	-	
Tilia sp.	+	+	-	-	
Ulmus sp.	+	+	+	-	
Viburnum opulus	+	+	+	-	

+ = present 1 = dominant
- = not present 2 = second in ranking

Table 2.5 The central river area, unworked and probably unworked wood. The Vlaardingen material from the Hazendonk is excluded.

site	Polderweg	De Bruin	Brandwijk-Kerkhof	dominance
Alnus glutinosa	+	+	+	1
Betula sp.	+	cf. +	-	
Cornus sanguinea	+	+	+	
Corylus avellana	+	+	+	
Euonymus europaeus	+	-	-	
Fraxinus excelsior	+	+	+	2
Pomoideae	+	+	-	
Prunus avium	-	+	-	
Quercus sp.	+	+	+	2
Rhamnus cathartica	+	+	-	
Rhamnus frangula	+	+	-	
Salix sp.	+	+	-	
cf. Sorbus sp.	-	+	-	
Ulmus sp.	+	+	-	
Viburnum opulus	+	+	+	
Viscum album	+	+	-	

+ = present 1 = dominant
- = not present 2 = second in ranking

Table 2.6 The central river area, charcoal.

taxon / site	Polderweg	De Bruin	Hazendonk
Daldinia concentrica	+	-	-
Fomes fomentarius	+	+	-
Ganoderma lipsiense	+	+	-
Ganoderma lucidum	-	+	-
Ganodermum europaeum	+	-	-
Gloeophyllum trabeum	+	+	-
Hypoxylon sp./Ustulina sp.	-	-	+
Phellinus igniarius	+	-	-
Ustulina deusta	-	+	-

+ = present - = not present

Table 2.7 The central river area, fungi.

The identifications of fungi and mosses indicate the presence of well-developed woodland vegetation in the central river area. Table 2.7 shows the identifications of fungi from Polderweg, De Bruin and the Hazendonk. The fungi indicate the presence of old, weak and/or dead deciduous trees. Identified host species are *Tilia* sp., *Quercus* sp. (/*Fagus* sp.) and *cf. Alnus* sp. (Bakels and Van Beurden 2001; Bakels *et al.* 2001). Other potential hosts present in the central river area are *Betula* sp. and *Corylus avellana*. At the Hazendonk, Brandwijk-Kerkhof and De Bruin, the moss species *Neckera crispa* was identified. *Neckera crispa* grows on roots and or trunks of trees in dark, humid to moist deciduous woodlands, on eutrophic or calcareous soil, on single trees in river forelands that get overflowed in winter, on coppices and sometimes on dead wood. At Brandwijk-Kerkhof, the moss *Anomodon viticulosus* was identified, which grows on the base of trunks (coppices) of trees in stands of willow, ash and elm and on single trees in river forelands (Touw and Rubers 1989).

The central river area at 5500-3400 BC can be characterised as a freshwater environment (see also paragraph 2.1.4). This is in the first place indicated by the presence of several freshwater molluscs found at the Hazendonk and Polderweg, and absence of molluscs indicative of brackish conditions. The absence of marine influence in the central river area is confirmed by almost complete absence of macroremains of halophytic plant taxa and presence of many glycophytic taxa (taxa that do not tolerate marine influence). There are only two macroremains identifications of taxa tolerating brackish conditions, *Najas marina* and *Zannichellia palustris*. The latter may represent a freshwater species or a brackish water species, depending on which subspecies it concerns. There are also some pollen identifications that suggest a very limited component of marine influence (presence of pollen grains of *Plantago coronopus* (square 57 at the Hazendonk, appendix III; coprolites of De Bruin, Bakels *et al.* 2001), *Glaux* sp. (core H1530 at the Hazendonk, Van der Woude 1983), pollen of Plumbaginaceae (*Armeria* sp. or *Limonium* sp.; core 2 at the Hazendonk, appendix III), and pollen of *Armeria* sp. (core 2114 and 2115 at the Hazendonk, Steenbeek 1980), and possibly pollen of *Artemisia* sp. and Chenopodiaceae). These identifications however hardly are meaningful when considering the small number of the relevant identifications and the time-scale of the pollen diagrams. The occurrence of this pollen of halophytic taxa must therefore be explained by long-distance transport or occasional transport by water from the sea during extreme weather conditions.

The difference between dryland and wetland vegetation was not always as strict as suggested above. Transitional vegetation types may especially have been present on the slopes of dryland elements in the landscape where gradients of several abiotic factors must have been present (water, nutrients, soil formation, *etc.*). The precise composition and character of the woodland of dry terrain is difficult to reconstruct since it may concern vegetation types that hardly exist nowadays in the natural vegetation of northwestern Europe, such as alder carr mixed with trees that are usually considered as dryland trees (see appendices II and III; Kooistra *et al.* 2006; Sass-Klaassen and Hanraets 2006).

The analysis of changes in the assemblages of unworked wood and charcoal can provide information on changes in the vegetation, if assuming that these assemblages were not subject of human selection (see also paragraphs 2.8.3.7 and 8.7). The unworked wood of Polderweg shows a decrease in *Salix* sp. that appears to be related to decreasing activity of a crevasse channel during occupation. At De Bruin, the decrease in *Quercus* sp. and *Corylus avellana* and an increase in *Cornus sanguinea*, *Fraxinus excelsior* and *Ulmus* sp. probably represent the gradual submerging of the dune. The unworked wood of the Hazendonk only shows a minor increase in *Fraxinus excelsior*, but the number of wood remains from this site is restricted. Analysis of changes in the charcoal assemblages through time is possible for Polderweg and De Bruin only. At Polderweg, there is a trend that *Corylus avellana* decreased and that *Alnus* sp. increased. At De Bruin, *Corylus avellana*, *Viburnum opulus*, *Ulmus* sp. and *Salix* sp. decreased through time, and *Alnus* sp. and *Cornus sanguinea* increased. The decrease in *Corylus avellana* and the increase in *Alnus* sp. in the charcoal spectra of both sites can be related to the gradual submerging of the dunes. For the other taxa mentioned, the relation between the observed changes and the environmental conditions is less clear.

2.8.3 Human impact

2.8.3.1 Pollen diagrams

Changes in pollen diagrams from the studied sites in the central river area that certainly correspond with anthropogenic influence on the vegetation at specific sites or during specific occupation phases are: a decrease in *Tilia* sp., *Quercus* sp., *Fraxinus excelsior*, *Corylus avellana*, Cyperaceae, monoletae psilatae fern spores, an increase in *Quercus* sp., *Betula* sp., *Hedera helix*, *Corylus avellana*, *Rhamnus cathartica*, *Viburnum opulus*, *Cornus sanguinea*, *Artemisia* sp., *Plantago lanceolata*, *Persicaria* sp., Cerealia-type, *Allium* sp., *Pteridium* sp., *Polypodium* sp., Poaceae, Cyperaceae, *Alnus* sp., *Humulus lupulus*, *Calystegia* sp., *Urtica dioica*, *Lythrum salicaria*, *Sparganium erectum*-type, *Mentha*-type, *Symphytum* sp., *Solanum dulcamara*, *Lycopus europeus*, *Eupatorium cannabinum*, *Filipendula ulmaria*, *Lotus uliginosus*, *Galium*-type, *Thalictrum* sp., Ranunculaceae, Apiaceae, Brassicaceae, Asteraceae tubuliflorae, Caryophyllaceae and Rubiaceae. The effect of anthropogenic influence on a single taxon (increase or decrease) varies for some taxa and is not the same at all sites and during all occupation phases (this is especially relevant for *Quercus* sp., *Corylus avellana* and Cyperaceae that are mentioned above twice, see the appendices and chapter 8 for more information on the effect of human impact on these taxa).[10] The variation in the signals of human impact can be related to differences in the vegetation and in the unique character of the human activities at specific locations and during specific phases. Signals of human impact in pollen diagrams are generally contemporaneous with occupation. However, some diagrams of the Hazendonk show an increase in *Lythrum salicaria*, *Solanum dulcamara*, *Sparganium erectum*, Apiaceae and Rubiaceae only after occupation, representing a succession stage characteristic of the period after occupation and before complete recovery of the vegetation.

The observed changes indicate the disturbance of both the dryland and the wetland vegetation due to grazing by domestic animals and the creation of small-scale clearances by people. These open patches in the dryland vegetation and bordering wetland woodland vegetation, probably several tens to maximal several hundreds of square metres, resulted in the increased presence and variety of shrubs and herbs that prefer light, disturbance of the soil and eutrophic conditions (*e.g.* nitrate and ammonia). The clearances can be interpreted primarily as space used for occupation, daily living and activities of people and animals (which were not purely restricted to the dryland terrain). It is therefore unlikely that the small clearings were created to attract game or did attract any game (*e.g.* Bos *et al.* 2005; Mellars and Dark 1998). The clearances may have resulted in an

10 Comparison of human impact at Brandwijk-Kerkhof and the Hazendonk indicates that the model of the Hazendonk (see fig. III.26) is not completely representative of human impact at comparable phases (with crop plants) at Brandwijk-Kerkhof.

increased presence of trees and shrubs with edible fruits. The pollen diagrams of the central river area do not support large-scale deforestation of vast stretches of the dryland vegetation (many hundreds of square metres). At the Hardinxveld sites and Brandwijk-Kerkhof, large-scale deforestation is rejected since it is difficult to recognise human impact at all, except for the late phases at Brandwijk-Kerkhof. At the Hazendonk, large-scale deforestation is rejected since there are considerable differences in the vegetation on the slope of the dune over only a few metres distance. This result would not have been obtained if the major part of the dryland vegetation was cleared.[11] Nevertheless, the presence of vegetation on the slopes of the dune hampers to reconstruct the precise degree of deforestation on top of the dune. The pollen diagrams do not support large-scale burning of wetland vegetation either. The character of human impact in the exploitation area of the sites, *i.e.* in the remaining wetland at some further distance of the sites, remains unknown. The diagrams of Van der Woude (1983) indicate that the evidence of human impact in the wetlands at 1 to 3 km from the inland dunes is small.

2.8.3.2 Distinction between human impact and natural causes of disturbance

The pollen diagrams from the central river area show a trend that it is not possible to accurately recognise human impact at sites without crop plants (Polderweg, De Bruin and early phases of Brandwijk-Kerkhof, with exception of a single phase at De Bruin). In contrast, it is possible to recognise human impact at sites with crop plants (late phases of Brandwijk-Kerkhof and all phases of the Hazendonk). The implications of this result are discussed below.

The evidence of human impact in the diagrams of Polderweg and De Bruin is weak. It is difficult to relate the observed changes to human impact since there are various natural processes that result in disturbance of the vegetation as well (see Brown 1997; Timpany 2005). It is expected that these factors blur signals of human impact in pollen diagrams or even give a similar signal. It concerns for example a) disturbance of the vegetation by wild animals such as wild boars and beavers, b) the rise of the ground water level and c) changes in the water activity such as the development, presence and abandonment of channel tributaries. Other natural processes may play a role as well. As a result, it is not always possible to conclude whether changes in a pollen diagram represent human impact or not. Ad a: beavers were present in high numbers in the region and must have influenced the vegetation by foraging and lodge building. However, large-scale influence of beavers on the natural vegetation has not been demonstrated. It can be hypothesized that beavers did not create ponds on a large scale since lakes with considerable depth were already present on a large scale. Ad b: the gradual rise of the ground water level resulted in gradual submerging of the dryland dune vegetation. This resulted in the death of trees and a gradual decrease in the pollen rain of relevant taxa (see Hamburg and Louwe Kooijmans 2001, 89 and the pollen diagrams of Polderweg and the Hazendonk). Ad c: the influence of various types of changes in water activity is not known in detail for all studied sites (*e.g.* the development of channel tributaries at some distance of a site, the frequency of flooding and high water levels).

Although it is hardly possible to distinguish human impact from natural disturbance in the diagrams of Polderweg, De Bruin and the early phases at Brandwijk-Kerkhof, this does not mean that anthropogenic influence was absent at these sites. Certain changes may still be related to anthropogenic influence. Additional arguments can sometimes give supportive evidence. It is for example possible to recognise the signal of human impact of the earliest phase of Brandwijk-Kerkhof (layer 30) since the pollen diagram, the macroremains diagram, the presence of sand, charcoal and bone remains all indicate the occurrence of changes that may be related to weak human impact. The combination of indications makes human impact a likely explanation (Out 2008a).

11 It is expected that large-scale deforestation of the dryland vegetation would have resulted in a pollen rain that is highly comparable between two samples points located at several metres from each other.

Factors that support the anthropogenic character of changes in the pollen diagrams of Brandwijk-Kerkhof and the Hazendonk (sites with crop plants) are the presence of Cerealia-type pollen[12], repetition of comparable patterns in diagrams during various occupation phases and at various sites, recovery of the vegetation, correlation with the presence of sand in organic sediments indicative of erosion of dryland patches, the presence of charcoal and archaeological remains in the investigated sediment indicative of occupation, and correspondence with the wood and charcoal assemblages.

2.8.3.3 Factors influencing the evidence of human impact in pollen diagrams

The pollen diagrams from the central river area demonstrate that the possibility to detect and define human impact is complicated. Firstly, human impact is difficult to detect in diagrams from certain sites despite intensive occupation, such as at Polderweg and De Bruin. In contrast, the on-site pollen diagrams of the Hazendonk show clear human impact, partly independent of the occupation intensity. Secondly, the influence of the distance from the sample point to the dry surface and refuse layers is not uniform. At the Hazendonk, the evidence of human impact decreases within 4 metres distance from the dune and refuse layers. In contrast, the evidence of human impact at Brandwijk-Kerkhof remains equal over 20 metres. The pollen diagram of De Bruin also indicates that distance alone does not explain the possibility to distinguish human impact. This diagram does not show signals of human impact during phases 1 and 3, despite the fact that the sample location was still located next to the dry surface (distance up to 8 metres) and within the refuse layer. These results either indicate that other factors than distance to the dry surface and the refuse layer are more important for the presence of signals of human impact, or that the distance to dry surface and the refuse layer does not always represent the distance to human activity at this site.

2.8.3.4 The influence of the introduction of agriculture on signals of human impact

In theory the pollen diagrams allow to investigate the influence of the neolithisation process on the strength of human impact, since the studied sites represent the transition from Late Mesolithic to Middle Neolithic. Neolithic occupation generally tends to result in stronger human impact, caused by changes in subsistence, changes in the use of the landscape and possible changes in attitude towards the landscape (Hodder 1990). It has nevertheless been proved that evidence of human impact in pollen diagrams can also be demonstrated for the Palaeolithic and Mesolithic (*e.g.* Bos and Janssen 1996; Bos and Urz 2003).

Firstly, it has been investigated whether the pollen diagrams of the central river area show indications of the presence of domestic animals. At the Hazendonk, both domestic animals and crop plants are present, which does enable to separate the both factors. At Brandwijk-Kerkhof, domestic animals were present during the early phases while crop plants were not, which enables to study the influence of the introduction of domestic animals. The evidence of human impact at Brandwijk during the early phases is restricted and does not fundamentally differ from human impact at Polderweg and De Bruin where domestic animals were not present during the majority of phases, while human impact in the later phases with crop plants is stronger. The number of domestic animal bones in the early layers of Brandwijk-Kerkhof is however very small, which reduces the validity of the results. Future study of pollen diagrams of comparable sites with domestic animals and without crop plants may give more information.

Secondly, it has been investigated whether the pollen diagrams show changes related to the introduction of crop plants. The pollen diagrams from the central river area show a trend that it is not possible to accurately recognise human impact at sites without crop plants, while in contrast it is possible to recognise human impact at sites with crop plants (see paragraph 2.8.3.2). This development could be explained by the introduction of crop plants. It must kept in mind that local crop cultivation is questionable for this region (see chapter 11).

12 Presence of Cerealia-type pollen alone is not considered as sufficient evidence to demonstrate human impact.

site and phase / factor	Polderweg	De Bruin	Brandwijk-Kerkhof, early phases	Brandwijk-Kerkhof, late phases	Hazendonk
crop plants	-	-	-	+	+
domestic animals	-	-/+	(+)	+	+
local cultivation	-	-	-	?	?
sedimentation rate	fast	fast	slow	slow	slow
occupation intensity	variable	variable	low	high	variable
site function	winter base camp	winter base camp/ seasonal extraction camp	seasonal extraction camp/base camp	seasonal extraction camp/base camp	extraction camp/ base camp?
catchment basin	?	?	?	?	?
distance to dry surface	large	small	small	small	small
distance to refuse layer	large	small	medium	small	small
visible human impact	no	no	no	yes	yes

- = not present

+ = present

-/+ = present during the latest phase

crop cultivation: ? = small-scale local cultivation or no cultivation

? = unknown

Table 2.8 The central river area, factors that interfere with the introduction of crop plants and that may have a confounding effect on the signal of human impact. The distance to the refuse layer for the early phases of Brandwijk-Kerkhof is labelled medium since the precise distance to the refuse layer is not known. The refuse layer of at least one early phase at Brandwijk-Kerkhof was documented at the southern side of the river dune only, but the analysed cores collected at the northern side of the dune still contained small fragments of archaeological remains, suggesting that the refuse layer was present there as well. See the text for more information.

In order to investigate whether the introduction of crop plants indeed resulted in stronger human impact, factors have been investigated that are possibly correlated to the introduction of crop plants and that may have a confounding effect on the signal of human impact. Instead of the introduction of crop plants, it may be these factors that are the cause of an increase in the evidence of human impact, while they are independent of the presence or absence of crop plants. Table 2.8 shows an overview of the possible confounding factors. The upper part of the table shows variables that are fixed, while the lower part of the table shows variables that represent research methods. The last row shows the result. This table does not relate to the pollen diagrams that were sampled at off-site locations (the diagram of De Bruin presented in appendix I.6.2 and the pollen diagrams of the Hazendonk of Van der Woude), since in those studies the large distance between the sample locations and the location of occupation hampers to detect any evidence of human impact in these diagrams at all, independent of the phase of neolithisation of the sites (see appendices I and IV). The assessment of local crop cultivation is an interpretation. Occupation intensity is an interpretation of the archaeological refuse layers (extent, thickness). Distance from the sample location to the dry dune surface and especially the distance to the refuse layer are assumed to be indicative of the distance to human activity.

Some factors in table 2.8 are not confounded with the presence of cereals and cannot explain the increased evidence of human impact at sites with cereals. Firstly, occupation intensity is probably no confounding factor since intensive occupation does not automatically result in clear evidence of human impact (see also the previous paragraph). Secondly, there are no indications that the distance to the dry surface and the distance to the refuse layer are confounding factors, and these factors cannot explain the observed differences in the possibility to detect human impact. For example, differences between distances at Polderweg and De Bruin do not result in differences in the evidence of human impact.

Further, there are some other factors that are confounded with the presence of cereals, and these may be the cause of the increased evidene of human impact at sites with cereals. Firstly, the sedimentation rate is a confounding factor that may explain the increased evidence of human impact at sites with cereals, since considerable deposition of clay occurred repeatedly at Polderweg and De Bruin (in addition to peat formation), while primarily calm peat formation took place at Brandwijk-Kerkhof and the Hazendonk. This difference can be explained by a decrease in the rate of the water level rise during the second part of the Holocene (see Cohen 2005a). The rapid deposition of clay at Hardinxveld-Giessendam may have blurred the pollen signal and may restrict the possibilities to detect human impact in the pollen diagrams. The differences in sample interval between the various sites may play a role here as well (large for Hardinxveld and small for the Hazendonk), since evidence of human impact at Hardinxveld-Giessendam may be hidden in between analysed spectra.

Secondly, the presence of domestic animals is a confounding factor that hampers the reconstruction of the influence of the introduction of crop plants on human impact. Living domestic animals were absent during most phases at Polderweg and De Bruin, where human impact is minimal, and living domestic animals were present during the late phases at Brandwijk-Kerkhof and the Hazendonk, where there is clear evidence of human impact. An exception is the limited evidence of human impact during the early phases at Brandwijk-Kerkhof, despite the presence of domestic animals. However, this could be explained by the low occupation intensity and the small number of domestic animals. In addition, during the early phase (layer 30) at Brandwijk-Kerkhof only goat/sheep were present, while cattle were not attested. Therefore, the presence of cattle is certainly confounded with the presence of cereals at the sites.

Thirdly, the size of the catchment area of the studied pollen cores is not known for the studied sites, but it is assumed that it was small (some square metres up to tens of square metres). The reconstruction of the development of the vegetation through time does not give a reason to assume that the catchment area differed between sites. Nevertheless, the data indicate that differences may have existed, and that this possibly influences the possibility to detect human impact.[13] Therefore, it cannot be excluded that the catchment area represents a variable that is confounded with the presence of crop plants that could explain the different evidence of human impact between sites without and with cereals.

Finally, site function may be a confounding factor, although it can be questioned how a shift from winter base camps to seasonal extraction camps would result in stronger human impact in pollen diagrams. Interestingly, site function is interrelated with seasonality, for which some more information is available. The seasonality of occupation in the central river area shows a shift from winter occupation to occupation during various seasons and to increased summer occupation. Thus, a shift towards more summer occupation appears to be confounded with the presence of cereals. In contrast to the previous confounding factors, this factor supports a causal relationship between the presence of cereals and the increased evidence of human impact, since summer occupation allows local crop cultivation and/or since local cultivation could have been a reason for summer occupation.

Summarising, there is a trend that human impact at the sites in the central river area increases through time that may be related to the neolithisation process, but it is not possible to conclude whether the presence of cereals alone explains this increase. On the one hand, indications of a shift towards multi-seasonal occupation including summer occupation support such a causal relation. On the other hand, the factors of sedimentation, domestic animals and possibly catchment basin could also explain the observed increase in human impact. Therefore, the relationship between the presence of cereals and the strength of human impact remains a subject for further investigation.

2.8.3.5 Macroremains diagrams

In addition to pollen diagrams, it is also possible to use macroremains diagrams to detect human impact. Macroremains diagrams are available for Polderweg, De Bruin, Brandwijk-Kerkhof and the Hazendonk. The volume of the samples and the sample frequency of the available diagrams vary. At first, the macroremains diagrams confirm the pollen diagrams and indicate deforestation, an increase in shrubs, an increase in herbs including ruderals and nitrophilous taxa, in a single case the presence of crop plants, and partial recovery of the vegetation. Secondly, the diagrams show a trend that occupation horizons are characterised by an increase in the number of macroremains and the number of different taxa (see also appendix IV.7), although this increase cannot be observed in all diagrams that reflect occupation. It often concerns an increase in herbs, on the one hand herbs that are part of the natural vegetation and on the other hand herbs that are indicative of disturbance of the environment. An increase in macroremains and diversity can clearly be observed in diagrams of Brandwijk-Kerkhof and the Hazendonk, where (some) occupation horizons can be recognised relatively easily. In the diagrams of core 2, core 3 and M87 of the Hazendonk, the sample interval is regular throughout the whole core, which excludes that the sample interval influences the chance to find new taxa.

It is possible that the increase in macroremains and taxa in macroremains diagrams in occupation horizons is related to human occupation. The increase may be explained by disturbance of the environment during occupation and an increased presence of light and the increased flowering of herbs. A major restriction for the interpretation is that it is unclear whether it truly concerns an increase in numbers of macroremains and numbers of taxa since it is not known whether the sedimentation rate is constant through time before, during and after occupation.

13 The difference in the strength of the evidence of human impact on the dryland vegetation over distance between Brandwijk-Kerkhof and the Hazendonk suggests that the vegetation at Brandwijk-Kerkhof was more open than at the Hazendonk, which can be explained by a larger catchment basin at Brandwijk-Kerkhof. The results of De Bruin suggest that the effective area at this site was very small, which may also possibly explain the little evidence of human impact.

Interestingly, the observed increase in macroremains can be used to identify occupation horizons, despite it being unknown whether it concerns a true increase or not. To assure the relationship with human impact and occupation, an increase in macroremains and taxa in macroremains diagrams should preferably be used as indicator for occupation only in combination with other evidence of human impact, such as characteristic changes in pollen diagrams and presence of sand, charcoal and fragments of archaeological remains.

2.8.3.6 Carbonised macroremains of non-cultivated plants

Table 2.9 provides a list of the taxa other than cereals found in a carbonised state for Polderweg, De Bruin, Brandwijk-Kerkhof, the Hazendonk, Zijdeweg, Rechthoeksdonk and Meerweg, distinguishing between the absence and presence of crop plants at sites. The crop plants and ruderals are discussed in the paragraphs below.

It is assumed that the carbonised state of macroremains indicates that people handled the macroremains. In an ecological sense, the taxa found in a carbonised state represent woodland of dry terrain, ruderals, wetland woodland, marsh vegetation and water plants. In a functional sense, they represent amongst others potential arable weeds and potential use plants including food plants. In addition, the assemblage contains a large group of taxa that are seldom found in a carbonised state and for which the function is not known. These taxa may represent use plants with an unknown function or plants that became carbonised only accidentally (see chapter 9). The taxa that are present at most sites and phases in a carbonised state are *Corylus avellana* and *Galium aparine*. *Corylus avellana* probably represents a food plant. *Galium aparine* may have had a similar function although this is not precisely clear (see paragraph 9.3.1).

site and phase	Polderweg	De Bruin	Brandwijk-Kerkhof, early phases	Brandwijk-Kerkhof, late phases	Hazendonk, phases 1 and 2	Hazendonk, phase 3	Hazendonk, VL phases	Zijdeweg	Rechthoeksdonk	Meerdonk
number of samples	74	92	18	47	11	9	17	1	1	1
taxon										
Woodland vegetation of dry terrain										
Acer campestre	-	+	-	-	-	-	-	-	-	-
Cornus sanguinea	-	+	-	+	+*	+	+	-	-	-
Corylus avellana	+	+	+	+	+*	+	+	-	-	+
Crataegus monogyna	-	+	-	-	+*	+	+	-	-	-
Hedera helix	+	-	-	-	-	-	-	-	-	-
Malus sylvestris	+	+	-	-	+*	+	-	-	-	+
Prunus spinosa	-	-	-	-	-	+	+	-	-	-
Quercus sp.	-	+	-	-	+*	-	+	-	-	-
Quercus sp., cupulae	-	-	-	+	-	-	-	-	-	-
Quercus sp., cupulae with content	-	-	-	-	-	-	+	-	-	-
Rosaceae	-	+	-	-	+*	-	-	-	-	-

Table 2.9 part 1.

taxon / site and phase / number of samples	Polderweg	De Bruin	Brandwijk-Kerkhof, early phases	Brandwijk-Kerkhof, late phases	Hazendonk, phases 1 and 2	Hazendonk, phase 3	Hazendonk, VL phases	Zijdeweg	Rechthoeksdonk	Meerdonk
number of samples	74	92	18	47	11	9	17	1	1	1
Woodland vegetation of dry terrain (cont.)										
Rubus fruticosus	-	-	-	-	-	+	-	-	-	-
Tilia platyphyllos	-	+	-	-	+	+	-	-	-	-
Tilia sp.	-	-	-	-	+*	-	-	-	-	-
Viburnum opulus	-	-	-	-	+*	+	-	-	-	-
Chaerophyllum temulum	-	-	-	-	+*	-	-	-	-	-
Galium aparine	+	+	+	+	+	+	+	-	+	-
Galium odoratum	-	-	-	-	+	-	-	-	-	-
Ranunculus ficaria, tubers	+	+	-	-	+*	+	-	-	-	-
Urtica dioica	-	-	-	-	+*	-	-	-	-	-
Ruderals and pioneers of dry terrain										
Brassica rapa	-	-	-	-	-	+	-	-	-	-
Bromus secalinus-type	-	-	-	-	+*	-	-	-	-	-
Capsella bursa-pastoris	-	-	-	-	+*	-	-	-	-	-
Chenopodium album	-	-	-	+	+*	-	+	-	-	-
Elytrigia repens	-	-	-	-	+*	-	-	-	-	-
Fallopia convolvulus	-	-	-	-	+*	-	+	-	-	-
Persicaria lapathifolia	-	-	-	-	+	-	+	-	-	-
Persicaria maculosa	-	-	-	-	+*	-	-	-	-	-
Solanum nigrum	-	-	-	+	+*	-	+	-	-	-
Veronica hederifolia	-	-	-	-	-	+	-	-	-	-
Carr and marsh vegetation										
Alnus glutinosa	-	-	+	+	+*	-	+	-	-	-
Alnus glutinosa, cones	-	-	-	+	+*	-	-	-	-	-
Ajuga reptans	-	-	-	-	-	+	-	-	-	-
cf. Berula erecta	-	-	-	-	+*	-	-	-	-	-
cf. Euphorbia palustris	-	-	-	-	+*	-	-	-	-	-
Galium palustre	-	-	-	+	-	-	-	-	-	-

Table 2.9 part 2.

taxon / site and phase / number of samples	Polderweg 74	De Bruin 92	Brandwijk-Kerkhof, early phases 18	Brandwijk-Kerkhof, late phases 47	Hazendonk, phases 1 and 2 11	Hazendonk, phase 3 9	Hazendonk, VL phases 17	Zijdeweg 1	Rechthoeksdonk 1	Meerdonk 1
Carr and marsh vegetation (cont.)										
Iris pseudacorus	+	-	-	-	-	+	+	-	-	-
Lycopus europaeus	-	-	-	+	-	-	-	-	-	-
Menyanthes trifoliata	-	-	-	-	-	+	-	-	-	-
Oenanthe aquatica	-	-	-	-	+*	-	-	-	-	-
Phragmites australis	-	-	-	+	-	-	-	-	-	-
cf. P. australis, stem fragments	-	-	-	+	+*	-	-	-	-	-
Rumex cf. crispus	-	-	-	-	+*	-	-	-	-	-
Schoenoplectus lacustris	-	+	-	-	+*	-	-	-	-	-
Schoenoplectus lac./tab.	-	+	+	+	-	-	-	-	-	-
Schoenoplectus tabernaemontani	-	-	-	+	-	-	-	-	-	-
Sparganium erectum	-	-	+	-	+*	-	-	-	-	-
Open water vegetation										
Nymphaea alba	-	-	-	+	+*	-	+	-	-	-
Trapa natans	+	+	-	+	-	+	-	+	-	-
Ecologically indeterminate										
Lathyrus palustris/Vicia cracca	-	-	-	-	-	+	-	-	-	-
Mentha aquatica/arvensis	-	-	-	-	-	-	+	-	-	-
Poa annua/Phleum sp.	-	-	-	-	+*	-	-	-	-	-
Poa sp.	-	-	-	+	-	-	-	-	-	-
Poaceae, small	-	+	-	-	-	-	-	-	-	-
Rumex sp.	-	-	-	+	+*	-	-	-	-	-
Scrophularia sp./Verbascum sp.	-	-	-	-	-	-	+	-	-	-
Veronica austriaca/chamaedrys	-	-	-	-	+*	-	-	-	-	-

VL = Vlaardingen + = present - = not present
* = found in the concentration of carbonised cereals (phase Hazendonk 1)

Table 2.9 The central river area, non-cultivated carbonised macroremains, part 3.

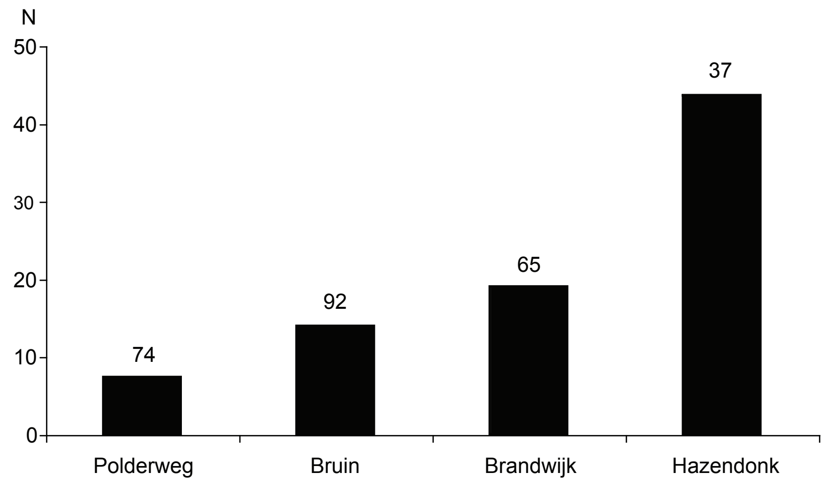

Figure 2.6 Polderweg, De Bruin, Brandwijk-Kerkhof and the Hazendonk (Vlaardingen phases excluded), the number of non-cultivated taxa from which carbonised macroremains were found. The number above the bars shows the number of samples included in the analysis.

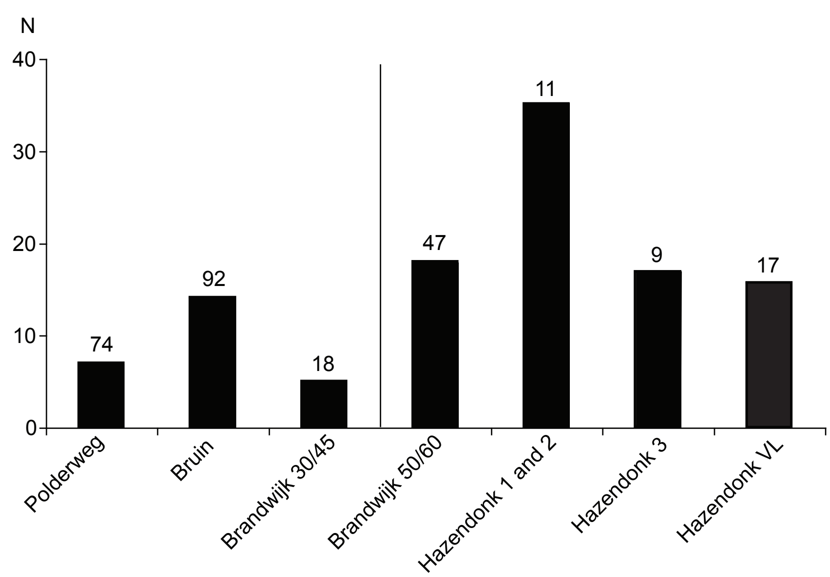

Figure 2.7 Polderweg, De Bruin, Brandwijk-Kerkhof and the Hazendonk, the number of non-cultivated taxa from which carbonised macroremains were found. The line in the middle of the figure separates sites without and with crop plants. The number above the bars shows the number of samples included in the analysis. VL = Vlaardingen.

The comparison of the main sites Polderweg, De Bruin, Brandwijk-Kerkhof and the Hazendonk (Late Neolithic Vlaardingen phases excluded) shows an increase in the number of non-cultivated carbonised taxa through time (see fig. 2.6). This trend cannot be related to the number of analysed samples since the number of samples was maximal at the sites Polderweg and De Bruin and minimal at the Hazendonk. The development through time suggests that the neolithisation process could have played a role in the increase. Indeed, there appears to be an increase in non-cultivated carbonised taxa after the introduction of crop plants (see fig. 2.7).[14] However, analysis of the separate phases of the Hazendonk (Swifterbant culture, Hazendonk group and Late Neolithic phases) indicates that the increase in the number of carbonised taxa during the early phases at the Hazendonk may be explained by the context of the relevant samples. Most carbonised taxa were found in the material of the refuse layers dating to the Swifterbant culture that contained concentrations of carbonised crop plants, while comparable concentrations are absent in other phases and at other sites. Therefore, the relation between the increase in the number of carbonised taxa and the introduction of crop plants remains weak.

taxon \ category	natural vegetation	worked wood/ artefacts
Acer sp.	+/-	+/-
Alnus glutinosa	++	++
Betula sp.	+/-	-
Cornus sanguinea	+	+
Corylus avellana	++	+
Euonymus europaeus	+/-	+
Fraxinus excelsior	++	++
Pomoideae	+	+
Prunus padus	+/-	-
Quercus sp.	++	++
Rhamnus cathartica	+	-
Rhamnus frangula	+/-	-
Salix sp.	+	+
cf. Sorbus sp.	+/-	-
Tilia sp.	+	+/-
Ulmus sp.	++	+
Viburnum opulus	+	+
Viscum album	+/-	-

++ = very frequent +/- = present/rare
+ = frequent - = not present

Table 2.10 The central river area, the frequency of trees and shrubs in the natural vegetation (based on various botanical sources excluding worked wood and artefacts) and as worked wood and wooden artefacts. The Vlaardingen material from the Hazendonk is excluded.

A selection of potential food plants that were found in a carbonised state are *Cornus sanguinea*, *Corylus avellana*, *Crataegus monogyna*, *Malus sylvestris*, *Nymphaea alba*, *Prunus spinosa*, *Quercus* sp., Rosaceae, *Rubus fruticosus*, tubers of *Ranunculus ficaria*, *Trapa natans*, and several herbs, grasses and sedges. Some more potential food plants were found in a waterlogged state, including *Sambucus nigra*, *Rubus caesius* and *Ribes* sp., a large variety of herbs and a considerable number of taxa with edible tubers and rhizomes (e.g. *Nuphar lutea*, *Typha* sp. and *Allium* sp.). Changes of the number of food plants though time are further discussed in chapter 9.

2.8.3.7 Wood and charcoal

The categories of worked and possibly worked wood are combined to compare the assemblages of the four main sites. Table 2.10 shows the frequency of trees and shrubs in the natural vegetation and in the assemblages of worked wood and artefacts. Artefacts dating to the period studied were mainly found at Polderweg and De Bruin. The table shows that taxa that were readily available in the natural vegetation were also often used for wood working. The table nevertheless tentatively supports selective use of wood based on the quality of the wood and the function of artefacts as well, since the data indicate that only a selection of the available taxa were used on a considerable scale (*Alnus glutinosa*, *Fraxinus excelsior* and *Quercus* sp.). Interestingly, the wood selected for specific artefacts compares well between the sites of Polderweg, De Bruin and the Hazendonk. This subject is further analysed in chapter 8.

14 The small number of carbonised taxa from the early phases of Brandwijk-Kerkhof may also be related to restricted sampling possibilities.

The charcoal assemblage (see also table 2.6) provides information on the fuel collection strategy. The charcoal of Brandwijk-Kerkhof indicates that people used brushwood as source of fuel. At Polderweg people used brushwood and humid wood. At De Bruin during phase 1, people often used fresh wood as source of fuel. During phase 2, people may have used dead wood. During phase 3, people used dry, dead wood as fuel (see the appendices for more details). For De Bruin and Brandwijk-Kerkhof, the charcoal assemblages suggest that there was no selection of fire wood based on the qualities of the wood since there is no overrepresentation of taxa that are suited as fuel, and since the charcoal assemblage corresponds with the natural vegetation and the assemblage of unworked wood (but see the comments on changes in the charcoal through time at De Bruin, appendix I.6.4). At Polderweg, two pits that contain relatively much charcoal of either *Corylus avellana* or *Euonymus europaeus* probably indicate selective use of wood for fuel and/or for a (burned) artefact (see also chapter 8).

The Hardinxveld-Giessendam sites demonstrate that the bark of several trees was used for netting and possible other purposes (see appendix I). In addition to bark, an unidentified herb was used as well.

Information on possible management of shrubs and trees can be retrieved by analysis of the number of annual rings and the diameter of wood remains. However, the sample size of relevant wood remains from single structures that could have shown management of the vegetation is too small for all sites.

2.8.4 Crop cultivation

2.8.4.1 Suitability of the landscape for cultivation

At the moment of introduction of agriculture, the central river area was a wetland region with small patches of dry terrain that gradually decreased in size. Wetland terrain, even the higher parts that were covered with alder carr, was not suitable for crop cultivation since the upper part of those soils were saturated with water during a large part of the year (Stortelder *et al.* 1998). Only dry terrain with a water table sufficiently below the surface was suitable for crop cultivation. Dryland patches present in the landscape were inland dunes, levees, and possibly crevasse splays and channel belts (see paragraph 2.1), consisting of sand and/or clay.

For the inland dunes, it can be questioned whether the ground water table was high enough to enable crop cultivation. Nevertheless, the woodland present on the dunes increased the potential of the soil to retain the water due to the presence of woodland litter, organic matter, and capillary rise to roots (Brady 1990, 148). It can therefore be assumed that the surrounding woodland vegetation maintained a sufficient water level when crop cultivation was practised on a small scale on top of the dune. Large-scale crop cultivation may, however, have reduced the availability of water in the soil.

The presence of nutrients in the dune soils is not considered as a factor restricting the possibilities for cultivation. The soils were mesotrophic to eutrophic, and rich in humus and minerals (Berendsen 1997a; Hommel *et al.* 2002; Louwe Kooijmans and Mol 2001; Mol and Louwe Kooijmans 2001; this chapter). Occasional floods at the lower parts of the dunes and droppings of animals may have enriched the environment. Soil development had already started since the formation of the dunes (Younger Dryas), but the soils had probably not turned into podsols yet. Cultivation on the slopes of the dunes may have been advantageous due to more regular natural fertilisation by flooding. Erosion of the slopes may have been reduced by orientating small-scale arable plots parallel to the slope of the dune, reducing downwards transportation of water and sediment.

Natural levees and, if present, channel belts and crevasse splays would have been suitable for crop cultivation if their height above the mean ground water level was sufficient and if the flooding frequency would have been low enough, *i.e.* possibly during summer. The floods would have increased the fertility of the soil, and this may have been a reason to select the flooded locations in the landscape for cultivation. However, if cultivation was practised at inland dunes, the number of the dunes and their extent would however have been sufficient for the agricultural needs until the end of the Middle Neolithic. Moreover, extensive sandy soils were available up to tens of kilometres south of the central river area.

2.8.4.2 Crop plants

The main crop plants found in the central river area are *Triticum dicoccon* and *Hordeum vulgare* var. *nudum* (see appendices II and III for the precise identifications and paragraph 2.8.1 for the dating of the introduction of crop plants in the region). A single grain of *Triticum monococcum*-type found at Brandwijk-Kerkhof is interpreted as *Triticum dicoccon*, as are finds of *Triticum* sp. The remains of *Triticum dicoccon* and *Hordeum vulgare* var. *nudum* are mostly found in a carbonised state. Remains of *Triticum* sp. are dominant. The cereal remains are mostly found dispersed and in small numbers, as part of the settlement refuse. Interestingly, the assemblage of phase 1 of the Hazendonk contained concentrations of carbonised grains and chaff remains of both cereals. Moreover, these concentrations uniquely contained a large number of carbonised grains of *Bromus secalinus*-type, which possibly functioned as a crop plant at this site (Bakels 1981; Knörzer 1967). For the Neolithic wetland sites, the presence of such numbers of *Bromus secalinus*-type (or *Bromus* sp.) is exceptional and its gives the first occupation phase at the Hazendonk a unique signature (see also paragraph 2.8.4.4). In addition to emmer and naked barley, *Papaver somniferum* ssp. *setigerum* was found in a waterlogged state in layer 50 of Brandwijk-Kerkhof. The unique presence of *Papaver somniferum* gives this layer a specific signature.

In addition to the macroremains assemblages, the pollen diagrams of the studied sites show information on the presence of crop plants as well. The pollen diagrams of Brandwijk-Kerkhof show the presence of pollen grains of Cerealia-type from layer 50 and/or 60 onwards, which corresponds with the presence of macroremains at the site. The pollen diagrams of the Hazendonk show presence of pollen grains of Cerealia-type during the major occupation phases (appendices III and IV; Van der Wiel 1982). The pollen diagram of Polderweg shows the presence of grains of *Hordeum*-type. This pollen is interpreted as originating from a wild *Hordeum* species since macroremains of crop plants were not identified.

2.8.4.3 Arable weeds

Classical weed analysis is usually based on the analysis of macroremains found in a carbonised state found in concentrations of carbonised cereal remains, assuming that these concentrations represent crop products (*cf.* Hillman 1981, 1984). In the central river area, concentrations of carbonised crop plants are only present in the material of Hazendonk phase 1. The relevant assemblage is extensively discussed in appendix III. Unfortunately, it is not possible to exclude contamination of the crop product during the formation of this assemblage. It can only be concluded that the taxa present in the concentrations of the Hazendonk represent potential arable weeds.[15] The concentrations contain several species that do not occur at any of the other studied sites during the investigated period: *Elytrigia repens* and *Veronica austriaca/chamaedrys*. Together with the large numbers of *Bromus secalinus*-type, their presence supports the unique status of the concentrations.

The absence of macroremains concentrations that represent closed contexts makes the further weed analysis as commonly applied impossible. As an alternative, it has been investigated which taxa are found in a carbonised state in samples that contain carbonised remains of cereals. Secondly, investigation has been undertaken on how the assemblage of potential arable weeds changed after introduction of crop plants. Finally, it has been investigated whether the arrival of anthropochorous taxa can be related to the introduction of crop plants. This analysis can only function as an approach of weed analysis.

15 Potential arable weeds are defined in chapter 10.

Table 2.11 shows the taxa that have been found in a carbonised state in samples that contained carbonised remains of crop plants for different sites and phases separately (the Late Neolithic data of the Hazendonk are not included). The weak association with carbonised cereals indicates that these taxa may represent arable weeds. However, the large group of taxa shows a high ecological variety, and includes taxa that prefer ecological conditions that do not correspond with the ecology of arable plots. This makes it improbable that this group represents arable weeds only. Instead, it is more likely that only dryland ruderals and some herbs of the group ecologically indeterminate represent potential arable weeds (see table 2.11).

The second approach to identify potential arable weeds is based on the comparison of the presence of taxa before and after introduction of crop plants, *i.e.* the comparison of Hardinxveld-Giessendam and the early layers of Brandwijk-Kerkhof on the one hand and the late layers of Brandwijk-Kerkhof and the Hazendonk on the other hand (the Late Neolithic data from the Hazendonk are not included). The taxa included in this analysis are taxa preferring ecological conditions that are similar to those of arable weeds, and taxa that are known as arable weeds from other Neolithic cultures from Northwestern Europe. The ecological conditions of taxa were retrieved from Weeda *et al*. (1985-1994) and Schaminée *et al*. (1995-1999).

Table 2.12 shows the presence and absence of potential arable weeds in waterlogged and carbonised states before and after the introduction of crop plants. Firstly, the table shows that a large number of ruderals were already present in a waterlogged state before introduction of crop plants. These taxa cannot simply be considered as arable weeds at sites with crop plants since they may simply represent the natural vegetation (see also the discussion on anthropochores and apophytes below). Secondly, the number of potential arable weeds that have been found in a carbonised state increases strongly after introduction of crop plants (from one to ten species). The taxa found in a carbonised state at sites with cereals are more likely to represent arable weeds than those that were not found in a carbonised state, assuming that the seeds and fruits got carbonised during crop processing. However, not all weeds get carbonised during crop processing and it is therefore not excluded that some other taxa represent arable weeds as well. Thirdly, some taxa are only present at sites with crop plants: *Brassica rapa*/*Brassica* sp., *Lapsana communis*, *Polygonum aviculare*, *Rumex acetosella*[16], *Bromus secalinus*-type, *Elytrigia repens*, and *Veronica hederifolia*. The earliest presence of *Arctium cf. lappa*, *Phleum* sp./*Poa annua*, *Silene latifolia* ssp. *alba* and *Sonchus asper* remains unclear; identifications on genus level indicate that these species may have been present before the introduction of cereals. For the taxa that are found at sites with cereals only, it is probable that they represent arable weeds, and especially for the taxa found only in a carbonised state (*Bromus secalinus*-type, *Elytrigia repens*, and *Veronica hederifolia*). In contrast, *Rumex acetosella* was probably not a common arable weed in the central river area during the period studied since finds of this species dating to the Late Mesolithic/Early Neolithic are very scarce in this region and in other wetland regions studied.

In addition to the macroremains assemblages, the pollen diagrams also show the presence of several taxa that may have functioned as arable weeds. Taxa that are only attested at sites/phases with crop plants are *Polygonum aviculare*-type, *Fallopia convolvulus*-type and *Plantago major/media*. The value of absence of pollen identifications of these taxa at sites/phases without crop plants however remains questionable since the taxa do not produce much pollen and since there are more pollen cores available for sites with crop plants than for sites without crop plants. Indeed, the macroremains assemblage contrastively shows that fruits of *F. convolvulus* have been found at sites without crop plants. Nevertheless, the absence of *Polygonum aviculare* is indicated by both the analysis of macroremains and pollen. This is remarkable since this species is known as a plant indicative of tread and not specifically as an arable weed.

16 Van der Wiel 1982.

site and phase / number of samples / taxon	Brandwijk-Kerkhof, late phases	Hazendonk, phases 1 and 2	Hazendonk, phase 3
number of samples	14	10	4
Woodland vegetation of dry terrain			
Cornus sanguinea	+	+	+
Corylus avellana	+	+	+
Crataegus monogyna	-	+	+
Malus sylvestris	-	+	+
Malus sylvestris, parenchyma	-	-	+
Prunus spinosa	-	-	+
Quercus sp.	-	+	-
Quercus sp., cupulae	+	-	-
Rosaceae	-	+	-
Rubus fruticosus	-	-	+
Tilia platyphyllos	-	+	+
Tilia sp.	-	+	-
Viburnum opulus	-	+	+
Chaerophyllum temulum	-	+	-
Galium odoratum	-	+	-
Ranunculus ficaria, tubers	-	+	+
Urtica dioica	-	+	-
Ruderals and pioneers of dry terrain			
Brassica rapa	-	-	+
Bromus secalinus-type	-	+	-
Capsella bursa-pastoris	-	+	-
Chenopodium album	+	+	-
Elytrigia repens	-	+	-
Fallopia convolvulus	-	+	-
Galium aparine	+	+	+
Persicaria maculosa	-	+	-
Solanum nigrum	+	+	-
Veronica hederifolia	-	-	+

Table 2.11 part 1.

taxon	Brandwijk-Kerkhof, late phases	Hazendonk, phases 1 and 2	Hazendonk, phase 3
site and phase			
number of samples	14	10	4
Carr and marsh vegetation			
Alnus glutinosa	+	+	-
Alnus glutinosa, cones	+	+	-
Ajuga reptans	-	-	+
cf. Berula erecta	-	+	-
cf. Euphorbia palustris	-	+	-
Galium palustre	+	-	-
Menyanthes trifoliata	-	-	+
Oenanthe aquatica	-	+	-
Phragmites australis, stem fragments	+	cf. +	-
Rumex cf. crispus	-	+	-
Schoenoplectus lacustris	-	+	-
Schoenoplectus tabernaemontani	+	-	-
Sparganium erectum	-	+	-
Open water vegetation			
Nymphaea alba	-	+	-
Trapa natans	+	-	+
Ecologically indeterminate			
Lathyrus palustris/Vicia cracca	-	-	+
Poa annua/Phleum sp.	-	+	-
Poa sp.	+	-	-
Rumex sp.	-	+	-
Veronica austriaca/chamaedrys	-	+	-

+ = present - = not present

Table 2.11 The central river area, macroremains of non-cultivated plants found in a carbonised state in samples that contained carbonised crop plant remains, part 2.

crop plants present	-		+	
category	C	W	C	W
taxon				
Atriplex patula/prostrata	-	+	-	+
Chenopodium ficifolium	-	+	-	+
Galeopsis bifida-type	-	+	-	+
Galium spurium	-	+	-	+
Mentha aquatica/arvensis	-	+	-	+
Persicaria lapathifolia	-	+	-	+
Poa sp.	-	+	-	+
Ranunculus repens-type	-	+	-	+
Rumex sp.	-	+	-	+
Silene sp.	-	+	-	+
Sonchus sp.	-	+	-	+
Stellaria aquatica/media	-	+	-	+
Stellaria media	-	+	-	+
Arctium sp.	-	+	-	-
Arctium cf. lappa	-	-	-	+
Chenopodium glaucum/rubrum	-	+	-	-
Chenopodium murale	-	+	-	-
Cirsium sp.	-	+	-	-
Lychnis sp./Silene sp.	-	+	-	-
Poa annua	-	+	-	-
Urtica urens	-	+	-	-

C = carbonised

W = waterlogged

crop plants present	-		+	
category	C	W	C	W
taxon				
Galium aparine	+	+	+	+
Bromus secalinus-type	-	-	+	-
Elytrigia repens	-	-	+	-
Phleum sp./Poa annua	-	-	+	-
Veronica hederifolia	-	-	+	-
Capsella bursa-pastoris	-	+	+	+
Chenopodium album	-	+	+	+
Fallopia convolvulus	-	+	+	+
Persicaria maculosa	-	+	+	+
Solanum nigrum	-	+	+	+
Brassica rapa	-	-	-	+
Brassica sp.	-	-	-	+
Galium sp.	-	-	-	+
Lapsana communis	-	-	-	+
Polygonum aviculare	-	-	-	+
Rumex acetosella	-	-	-	+
Silene latifolia ssp. album	-	-	-	+
Sonchus asper	-	-	-	+

+ = present

- = not present

Table 2.12 The central river area, potential arable weeds at sites and phases without and with crop plants.

Thirdly, it has been investigated whether the arrival of anthropochorous taxa is related to the introduction of crop plants. The introduction of potential weeds at the same time as the introduction of crop plants is especially relevant when the dispersal of taxa can be related to human activity. This is the case for anthropochorous taxa, which are taxa that depend on people for their distribution and persist only by direct or indirect human influence on the environment (Kreuz *et al.* 2005). An important mechanism of seed dispersal during the Neolithic is dispersal of crop products and sowing seed. However, it should be kept in mind that the introduction of animal husbandry might have resulted in the introduction of anthropochorous taxa as well. Information on whether taxa are anthropochorous is based on literature on the LBK (Kreuz 1990; Kreuz *et al.* 2005).

In the central river area, there are several taxa of which the first presence contemporaneous with the introduction of crop plants (see paragraph above) corresponds with their status as anthropochorous taxa. This concerns *Brassica rapa*/*Brassica* sp., *Bromus secalinus*-type, *Polygonum aviculare* and *Rumex acetosella*. If these four taxa are indeed anthropochorous and if these taxa were indeed absent before introduction of crop plants, it is probable that they represent arable weeds. The data of the other regions support such a status for *Brassica rapa*/*Brassica* sp., *Bromus secalinus*-type and *Polygonum aviculare*. Importantly, *Bromus secalinus* was also found in the concentrations of carbonised cereal remains at the Hazendonk, while the other taxa were not. The data additionally suggest that the following taxa could be anthropochorous: *Elytrigia repens*, *Lapsana communis* and *Veronica hederifolia*. *Lapsana communis* is however not known from the LBK as anthropochorous taxa but instead as an idiochorous species (not spread by people) (Kreuz *et al.* 2005). For the other two species such information is not available yet.

In contrast to the possible arrival of some anthropochorous taxa at the time of crop cultivation, some taxa that are generally considered as anthropochorous taxa are present in the region before introduction of crop plants (in a waterlogged state): *Atriplex patula/prostrata*, *Capsella bursa-pastoris*, *Chenopodium album*, *Fallopia convolvulus*, *Galium aparine*, *Galium spurium, Persicaria maculosa*, *Poa annua*, *Solanum nigrum* and *Stellaria media*. There are several hypothetical explanations.

1) The anthropochorous taxa are spread together with crop plants, and crop plants therefore must have been present at Hardinxveld-Giessendam Polderweg and De Bruin. This hypothesis is however rejected since it is not supported by the available data.

2) The anthropochorous weeds are unintentionally spread before the introduction of crop plants. A first possibility is that the taxa were introduced into the Dutch wetlands after contact with Neolithic cultures. Archaeological finds in the central river area indicative of contact with southern regions show that this is a possible explanation. Alternatively the dispersal could theoretically concern spread by contact between Mesolithic communities. This implies that the anthropochorous taxa were spread by people and/or animals but not necessarily with agriculture, for example attached to clothes, hairs or textiles, by the dropping of dung, or unintentional enclosure in containers. Acceptance of this hypothesis implies that taxa that are known as anthropochorous do not necessarily represent field weeds at the studied sites of the Swifterbant culture and Hazendonk group.

3) The taxa discussed here are not anthropochorous but were part of the natural vegetation and were not spread by people into the central river area. This is likely for various of the taxa. If this is the case, these taxa may represent apophytes (taxa that were part of the natural vegetation and became arable weeds after the introduction of crop cultivation; see also paragraph 10.4.2). An important alternative dispersal method for the assumed anthropochorous taxa is transport by river water. River banks represent a disturbed environment that shows similarities with a human-disturbed environment. This is a very likely explanation for the presence of assumed anthropochorous taxa in the central river area. Acceptance of this hypothesis implies that the anthropochorous state of taxa cannot be reconstructed by literature or parallels in the LBK anymore. It furthermore implies that taxa that are known as anthropochorous do not necessarily represent field

weeds at the studied sites of the Swifterbant culture and Hazendonk group. The hypothesis can be tested with archaeobotanical and palaeoecological data from the central river area, but unfortunately data older than the sites of Hardinxveld-Giessendam are not available. Similarly, presence of several presumed anthropochorous taxa before the introduction of agriculture is also uncertain for other parts of Northwestern Europe (*e.g.* the presence of *Capsella bursa-pastoris*, *Fallopia convolvulus* and *Solanum nigrum* in Denmark and Britain (Jensen 1987; Preston *et al.* 2004)).

2.8.4.4 Local cultivation

Crop plants were not present at Polderweg and De Bruin, and it is therefore concluded that crops were not cultivated at these sites. At Brandwijk-Kerkhof (late phases) and the Hazendonk crops formed part of the diet, as indicated by finds of macroremains, chaff and pollen of crop plants, as well as scarce querns. However, local crop cultivation at Brandwijk-Kerkhof and the Hazendonk is difficult to demonstrate or reject. The following forms of evidence possibly support local cultivation of crop plants: the presence of pollen of cereals, the evidence of small-scale deforestation in pollen diagrams of phases with crop plants that may indicate the presence of fields, the presence of macroremains of cereals including chaff remains of naked barley in good preservation state, the presence of concentrations of carbonised cereal remains at the Hazendonk (phase 1), the poor development of the grains in these concentrations, the presence of potential arable weeds in a carbonised state, the increase in carbonised potential weeds at sites with cereals compared with sites without cereals, the presence of grinding stones, and the presence of flint artefacts with possible sickle gloss resulting from crop processing at the Hazendonk (see also appendices II and III).

However, some of the above mentioned forms of evidence can be questioned. The presence of Cerealia-type pollen does not demonstrate local cultivation since most pollen of cereals is released during processing activities. The signals of human impact in pollen diagrams do not demonstrate the presence of fields and other factors of disturbance are not excluded. The macroremains of crop plants and arable weeds may have been brought in from elsewhere, while the weeds may also represent local disturbance indicators. The presence of chaff remains of naked barley is interpreted as being indicative of local crop cultivation by some authors but can also be the result of transport of naked barley in the ear. The presence of a concentration of carbonised cereals may be influenced strongly by use and deposition, such as an accident, instead of demonstrating cultivation. The development of the grains does not reject import. The querns only indicate grinding and not cultivation. The evidence of sickle gloss is not as convincing as the evidence from the coastal region.

The following arguments reject local crop cultivation: the limited surface of the inland dunes available for arable fields, absence of relatively large quantities of sand in the peat surrounding the studied sites and other dunes that is indicative of absence of substantial erosion that would be expected in the case of local crop cultivation on a large scale (pers. comm. Verbruggen 2006), the absence of signals of large-scale deforestation in pollen diagrams, the correlation between the presence of pollen of cereals and the presence of archaeological refuse (sand, charcoal and/or fine fragments of archaeological remains; *cf.* Bakels 1986), the difference in the crop and weed assemblage between phases and sites (unique presence of *Bromus secalinus*-type and *Papaver somniferum* during a single phase at a single site only), the absence of large numbers of convincing flint artefacts with sickle gloss and the absence of tillage marks.

Again, there are some refining remarks. The changes in the pollen diagrams and the limited surface of the dunes allow the possibility of small-scale local crop cultivation. This would not necessarily have resulted in the erosion of sand. In addition, cultivation may alternatively have occurred at other dunes in the region. The absence of sickles is not conclusive either since crop plants may have harvested in other ways that are not visible for us, or sickles may have been deposited at off-site locations. The absence of tillage marks is not conclusive either since excavation of the dunes in the central river area did not result in information on prehistoric soils; these soils are not present anymore due to erosion of the top of the dune during occupation and historic land use.

The data do not allow rejecting or confirming local arable farming at Brandwijk-Kerkhof and the Hazendonk for most phases. Nevertheless, it can be concluded that large-scale crop cultivation did not occur at both dunes. Small-scale crop cultivation is possible, as is importation of crop plants. For the first phase of the Hazendonk, the unique presence of *Bromus secalinus*-type in considerable quantities can be argued to indicate import of crop plants. Macroremains of this type were not found in the material of later phases of the Hazendonk except for half a grain in the second phase, and were not found at other sites in the central river area either, and only in small numbers in other regions (see appendix III.4 and paragraph 11.6.7).

2.9 Suggestions for further research

The introduction of crop plants in the central river area is documented relatively precise and the reconstruction of this process seems to be the most detailed of all wetland regions studied (see chapter 11). However, the available evidence still requires further refinement for the precise introduction period. Firstly, more detailed information could be obtained by dating the cereal grains of Brandwijk-Kerkhof, allowing distinction between the base and top of layer 50 (see appendix II). Secondly, excavation and representative sampling of various sites in the region will give relevant information as well (for example the dune site Rommertsdonk, occupied at 4460-4340 BC and 4290-4170 BC; Verbruggen 1992, or phase 0 at the Hazendonk).

The analysis of pollen cores for research on human impact at Mesolithic and Neolithic sites in the central river area shows the importance of research methods. Firstly, the distance between the sample location and the dry dune surface as well as the refuse layer play an important role in palynological research in this region. When studying human impact at the dryland patches, it is suggested to sample pollen cores maximally at several metres distance from the outer edge of the refuse layers (up to 25 metres). Off-site cores without a clear archaeological context do not give detailed information on human impact. Secondly, the comparison of the data of Brandwijk-Kerkhof and the Hazendonk has furthermore shown that it is very useful to analyse both pollen and macroremains from a transect of several cores at a single site. Thirdly, the precise effect of domestic animals in the pollen diagrams studied is hard to distinguish from human impact in general and should receive further attention, and should be combined with information from modern-day grazing studies. Finally, the relationship between changes in pollen diagrams and human impact could be further investigated by comparison with non-archaeobotanical data from the region.