From land to water

Kooistra, L.I.; Peeters, Hans

Chapter 6

From land to water

Geomorphological, hydrological and ecological developments in Flevoland from the Late Glacial to the end of the Subboreal

L.I. Kooistra & J.H.M. Peeters

6.1 Introduction

The previous chapters have discussed the prehistoric landscape of Flevoland in various ways. Chapter 3 showed that the dynamics of the landscape had a major impact on the texture of the subsurface, the formation of the buried archaeology and the potential for identifying and investigating sites. Chapters 4 and 5 present an account of the prehistoric inhabitants, who utilised a wide range of naturally available resources, and relied on a diverse range of landscape components for their survival. The close relationship between human and environment evidenced by the archaeological remains brings us, in this chapter, to the question of what the landscape of Flevoland looked like and how it changed over time.

The changes in the landscape could hardly be greater than those that occurred in Flevoland between the Late Glacial and the end of the Subboreal (c. 12,000 to 1100 BC). The climate, hydrological processes and developments in vegetation drove geomorphological processes, and vice versa. As a result, Flevoland developed during this period from a fluvioglacial and coversand region with a dry Arctic climate, through a number of transitional stages, into a region of extensive mires (including bogs) with a temperate climate.[488] Thanks to a wealth of geomorphological, hydrological and palaeoecological data collected since the 1930s, we can gain an impression of the landscapes that prehistoric man would have witnessed between roughly 12,000 and 1100 BC.

This chapter concentrates on describing the contemporary "living landscape" comprising the flora and fauna as components of the environment in which prehistoric man lived. By combining existing data on the landscape with an emphasis on the available palaeobotanical data, a new interpretation will be presented here that focuses on the character of the vegetation, and how it changed. This chapter therefore goes a step further than the previous chapters, where the main objective was to present a synthesis of *archaeological* information contained in reports, books and academic papers. The

488 Marshes (wet areas with herbaceous plants) and swamps (wet areas with trees) occur on mineral soils; mires are wet areas which develop on peat (incompletely decomposed organic matter). There are three types of mires mentioned in this chapter, fens (mires with herbaceous plants), carrs (mires with trees) and bogs (ombrotrophic mires with mainly bog-moss). For definitions see for example Pons 1992, 7-12; Casparie & Streefkerk 1992, 84-86; Van der Linden & Kooistra 2019.

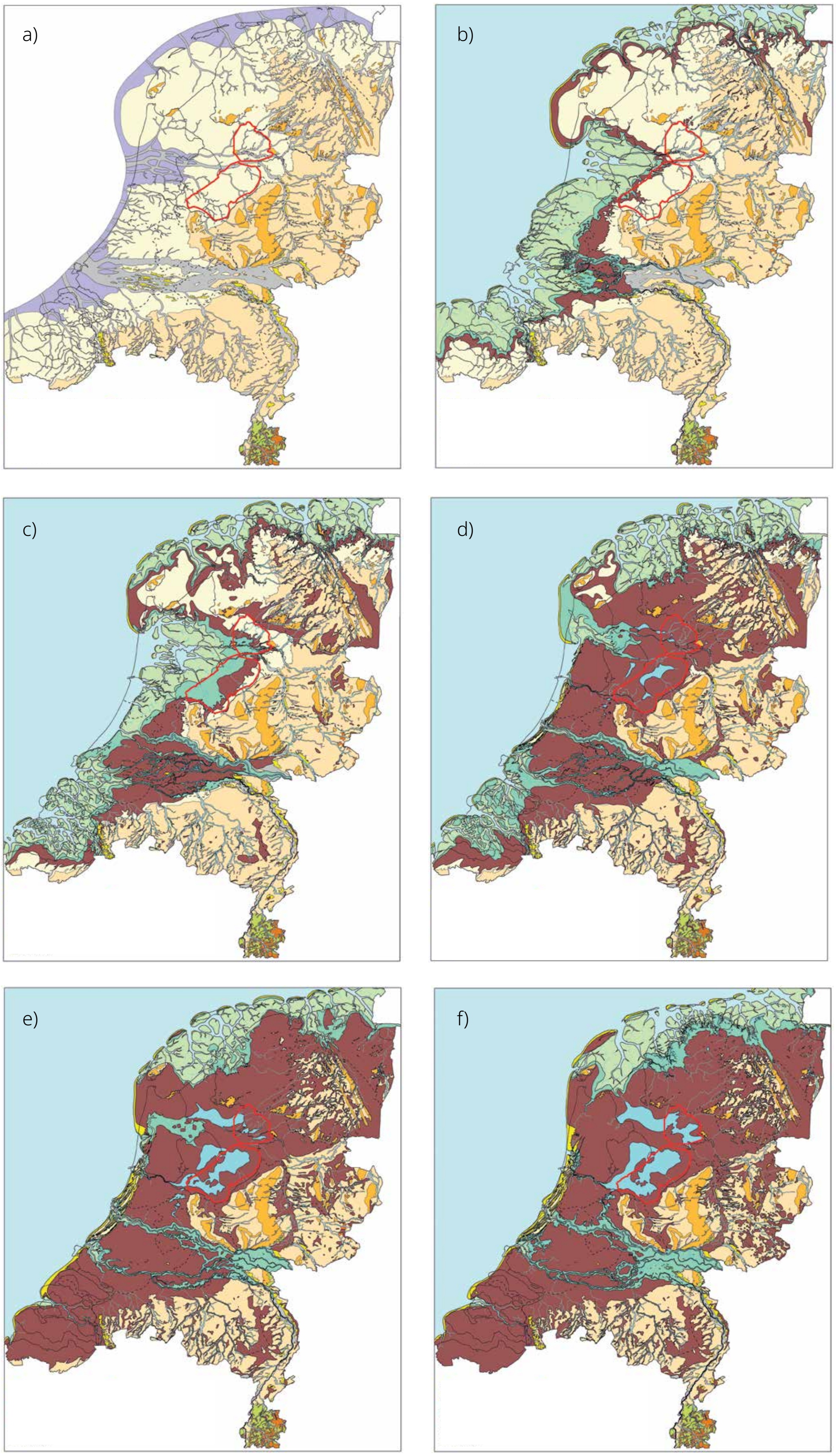
a)
b)
c)
d)
e)
f)

Figure 6.1 (previous page): Palaeogeographical maps of the Netherlands in the Holocene, with Flevoland in the centre (outlined in red). a) 9000 cal. BC; b) 5500 cal. BC; c) 3850 cal. BC; d) 2750 cal. BC; e) 1500 cal. BC; f) 500 cal. BC (after Vos & de Vries 2018; Vos *et al.* 2020).

- Beach barriers and dunes
- Tidal flats, rivervalleys and floodplains
- Peat
- Water
- Rivervalleys and brookvalleys
- Coversand
- Ice-pushed ridges
- River dunes
- Loess
- Tertiary and older sediments

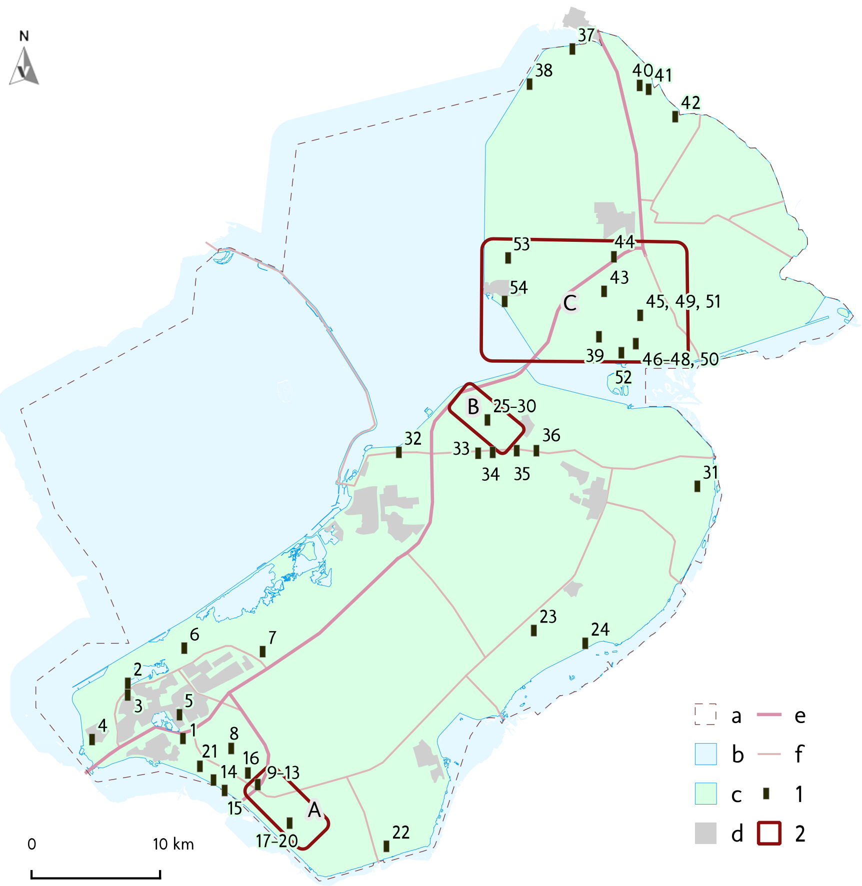

Figure 6.2: Topographical map of the province of Flevoland, with the investigations discussed in this chapter indicated. The numbers refer to the sites/locations in table 6.1. Legend: a) province border, b) water, c) rural areas, d) urban areas, e) highways, f) main roads, 1) sites/locations (table 6.1) and 2) microregions.

palaeobotanical data, which have largely been interpreted on the basis of very general models of vegetation succession, need, in contrast, to be reconsidered in preparation for the comprehensive synthesis of information on the prehistory of Flevoland that will be presented in the final chapter.

6.2 Study of the history of the Flevoland landscape in broad outline

This chapter relies on books, reports and academic papers on the geology, pedology and palaeobiology of Flevoland, the majority in Dutch, published between the 1930s and 2014 (table 6.1). The information refers to four spatial scales. In order to better understand the development of the landscape in Flevoland, the reconstructed global palaeogeographical development of the Netherlands (the supraregion) has been used as a basis. This development is summarised in a number of maps showing the distribution of the subsurface in each period, including the course of rivers and the bodies of water present (fig. 6.1).[489] In the 1990s and in the first decade of the 21st century, the development of the landscape in Flevoland as a whole (the

489 Vos *et al.* 2009; Vos *et al.* 2020.

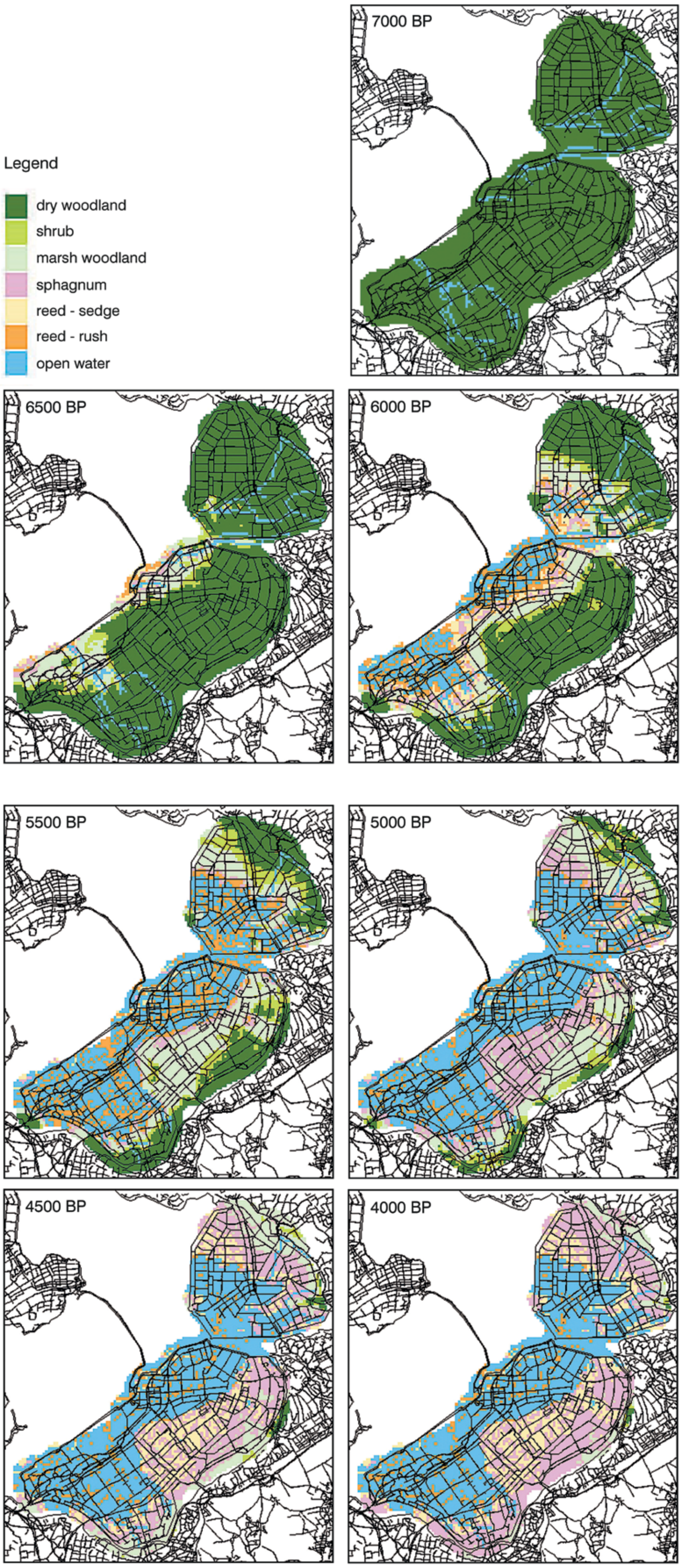

Figure 6.3: Landscape developments in Flevoland according to the 'Capillary-Growth-Erosion' (CGE) - model with intervals of 500 years (source: Peeters 2007).

Site number	Site name	Toponym/place name	Reference	Late Glacial	Preboreal	Boreal	Early Atlantic	Middle Atlantic	Late Atlantic	Atlantic	Subboreal	x-coordinate	y-coordinate
Zuidelijk Flevoland													
1	Almere kasteel	Kasteel, Fongerspad	Van Smeerdijk 2002	X	x	x	x	x	.	x	.	145.700	484.600
2	Almere-Noorderplassen-West	Plangebied 2X3, Noorderplassen-West	Van Smeerdijk 2006	.	.	.	.	x	.	.	.	141.413	488.886
3	Almere busbaan	Busbaan, Boring Almere 1	Bunnik & Verbruggen 2010	.	x	.	.	x	.	x	.	141.402	487.976
4	Almere Poort	Nederlandstraat / De Geest	De Moor *et al.* 2013	X	x	x	x	x	x	.	.	138.631	484.514
5	Almere-Veluwedreef	Veluwedreef	Makaske *et al.* 2002a	.	.	.	.	x	x	.	.	145.432	486.438
6	Almere-De Vaart	De Vaart (Gordingweg)	Van der Linden 2010	.	.	.	x	x	x	.	x	145.804	491.626
7	Almere-Kotterbos	Kotterbos	Van Heeringen *et al.* 2014; Kooistra 2014	.	.	.	.	.	x	.	x	151.900	491.355
8	Almere-Hout	Zwaanpad	Van Smeerdijk 2003	.	.	.	.	x	.	.	.	149.456	483.820
9	Almere-Hogevaart A27	Hogevaart-A27: opgraving	Hogestijn & Peeters (eds) 2001; Brinkkemper *et al.* 1999; Laarman 2001; Peeters *et al.* 2001; Peeters 2007; Van Rijn & Kooistra 2001; Visser *et al.* 2001	.	.	x	.	x	x	.	.	151.520	481.000
10	Almere Hoge Vaart A27	Hogevaart-A27	Spek *et al.* 2001a&b	.	.	.	.	x	x	.	.	151.520	481.000
11	Almere Hoge Vaart A27	Standaardkern	Gotjé 2001	.	.	.	.	x	x	.	x	151.520	481.000
12	Almere Hoge Vaart A27	Eem1-kern	Gotjé 2001	.	.	.	.	.	x	.	.	151.520	481.000
13	Almere Hoge Vaart A27	Eem2-kern	Gotjé 2001	X	x	.	.	.	x	.	.	151.520	481.000
14	Almere-Musweg	Musweg	Makaske *et al.* 2002a	.	.	.	.	.	x	.	x	148.079	481.359
15	Almere-Gooimeerdijk	Gooimeerdijk	Makaske *et al.* 2002a	.	.	.	.	.	x	.	.	148.946	480.549
16	Almere-Tureluurweg	Tureluurweg	Makaske *et al.* 2002a	.	.	.	.	.	x	.	.	150.753	481.906
17	Almere-Rassenbeektocht	Rassenbeektocht	Makaske *et al.* 2002b	X	.	.	.	.	.	.	x	153.500	478.800
18	Almere-Winkelweg	Winkelweg	Makaske *et al.* 2002b	.	.	.	.	.	x	.	.	155.867	477.500
19	Almere-Eemhof	Eemhof	Makaske *et al.* 2002b	.	.	.	.	.	.	x	x	155.200	475.267
20	Almere-Eemmeerdijk	Eemmeerdijk	Makaske *et al.* 2002b	.	.	.	.	.	.	.	x	154.500	475.333
17-20	Almere-bodembeschermings-gebied	Bodembeschermingsgebied	Gotjé 1997b; Makaske *et al.* 2002b	x	.	.	.	.	x	x	x	154.000	478.000
21	Almere MMM	Maatweg – Meesweg – Meentweg	Opbroek & Lohof (eds) 2012; Kooistra 2012a; Bos & Verbruggen 2012	.	x	x	x	x	x	.	x	147.020	482.428
22	Zuidelijk Flevoland-OZ-43	Scheepswrak OZ43	Van Smeerdijk 1989	.	.	.	.	.	.	x	x	161.533	476.200
A	Microregio Hoge Vaart		Peeters 2007	.	.	.	x	x	x	.	.		
Oostelijk Flevoland													
23	Biddinghuizen/ Biddingringweg	Biddinghuizen/ Biddingringweg	De Jong 1974	x	x	.	.	.	.	.	.	173.000	493.000
24	Flevoland I, II, III	Flevoland I, II, III	Havinga 1963	.	.	x	x	x	x	x	.	177.000	492.000
25	Dronten-N23	N23 / Hanzelijn	Hamburg (eds) 2012; Bouwman & Bos 2012; Kooistra 2012b; Van der Linden 2008; 2012	.	.	x	x	x	x	.	.	171.320	506.973
26	Swifterbant-S2	S2 (Kavel G41-G42)	Huisman *et al.* 2009; Prummel *et al.* 2009	.	.	.	.	.	x	.	.	168.133	510.867
27	Swifterbant S3	S3 (Kavel G43)	Casparie *et al.* 1977; Van Zeist & Palfenier-Vegter 1981 (1983); Cappers & Raemaekers 2008; Raemaekers *et al.* 2013; Schepers 2014a/b; Zeiler 1986	.	.	.	.	.	x	x	x	168.133	510.133

Table 6.1 (continued on the next page): List of literature references.

Site number	Site name	Toponym/place name	Reference	Late Glacial	Preboreal	Boreal	Early Atlantic	Middle Atlantic	Late Atlantic	Atlantic	Subboreal	x-coordinate	y-coordinate
28	Swifterbant S4	S4 (Kavel G43)	Bakels & Zeiler 2005; Brinkhuizen 1976; Clason & Brinkhuizen 1978; Hullegie 2009; De Jong 1966; Out 2009; Wolf & Cleveringa 2009; Zeiler 1997	.	.	.	.	.	x	.	.	168.140	510.140
29	Swifterbant S5	S5 (Kavel G43)	Van Rooij 2007; Van der Veen 2008	.	.	.	.	.	x	.	.	168.133	510.133
30	Swifterbant S25	S25 (Kavel H45)	Raemaekers *et al.* 2010	.	.	.	.	.	x	.	.	172.178	510.935
31	Dronten-tunnel Drontermeer	Tunnel Drontermeer	Prangsma (eds) 2009; Bos *et al.* 2009; Kooistra *et al.* 2009	.	.	.	x	.	.	.	.	185.723	504.223
32	Hanzelijn deelgeb. I&II	Hanzelijn deelgeb. I&II	De Moor *et al.* 2009	.	.	.	.	x	x	.	x	162.500	506.867
33	Hanzelijn deelgeb. VI	Hanzelijn deelgeb. VI	De Moor *et al.* 2009	.	.	.	.	x	.	.	.	168.667	506.800
34	Hanzelijn deelgeb. VII	Hanzelijn deelgeb. VII	De Moor *et al.* 2009	.	.	.	x	.	.	.	.	169.800	506.867
35	Hanzelijn deelgeb. VIII	Hanzelijn deelgeb. VIII	De Moor *et al.* 2009	.	.	.	x	x	.	.	x	171.667	507.000
36	Hanzelijn deelgeb. IX	Hanzelijn deelgeb. IX	De Moor *et al.* 2009	.	.	.	.	x	x	.	x	173.200	507.000
B	Microregio Swifterbant		See literature sites 25-36	.	.	x	x	x	x	.	.		
Noordoostpolder													
37	Kavel A3, A58	Kavel A3, A58	Wiggers 1955, 34-44	x	x	x	x	.	.	.	.	176.000	538.267
38	Kavel A19, A48	Kavel A19, A48	Wiggers 1955, 34-44	x	.	.	.	.	.	.	.	172.667	535.533
39	Kavel E155	Kavel E155	Wiggers 1955, 40-42	x	x	.	.	.	.	.	.	178.067	515.867
40	Kavel K24	Kavel K24	Wiggers 1955, 47-51	.	x	x	x	.	.	.	.	181.233	535.433
41	Kavel K25	Kavel K25	Wiggers 1955, 47-51	·	·	x	x	.	.	.	.	181.933	535.133
42	Noordoostpolder I, II, III	Noordoostpolder I, II, III	Havinga 1963	.	.	.	.	.	.	x	.	184.000	533.000
43	Emmeloord-J78	Nagelerweg, Kavel J78	Gehasse 1995; Zeiler 1997	.	.	.	.	.	x	.	x	178.467	519.400
44	Emmeloord/Nagele J97	J97	Bulten (eds) 2002; Van der Heijden 2000; Van Rijn 2002; Rompelman 2003	.	.	.	.	.	x	.	x	179.230	522.090
45	Schokland-I	Profiel I	Polak 1936	.	.	x	.	.	.	x	x	181.133	518.333
46	Schokland-II	Profiel II	Polak 1936	.	.	.	.	.	.	x	.	180.733	515.600
47	Schokland-III	Profiel III	Polak 1936	.	.	.	.	.	.	x	x	181.200	515.667
48	Schokland-VI	Profiel IV	Polak 1936	.	.	x	.	.	.	x	x	181.067	515.133
49	Schokland-SRW1	Sectie SRW1	Gotjé 1993	.	.	.	.	.	x	.	x	181.467	516.667
50	Schokland-ZP	Scectie ZP	Gotjé 1993	.	.	.	.	.	x	.	x	180.933	515.333
51	Schokland-P14	Kavel P14	Anscher & Gehasse 1993; Gehasse 1995; Cappers & Raemaekers 2008; Lauwerier *et al.* 2005; Luijten 1986 (Van Haaster 2010; Vernimmen 1999; 2004)	.	.	.	.	.	x	.	x	181.467	518.000
52	Schokland-Schokkerhaven-E170	Kavel E170	Cappers & Raemaekers 2008; Gehasse 1995; Weijdema *et al.* 2012; Luijten 1987; Van Haaster 2010; Vernimmen 1999; 2004	.	.	.	.	x	x	.	x	179.811	514.625
53	Urk-D56	Boorsectie D56	Gotjé 1993	.	.	.	.	.	x	.	x	171.000	522.000
54	Urk-E4	E4 (Domineesweg)	Peters & Peeters (eds) 2001; Cappers & Raemaekers 2008; Oversteegen 2001; Van Smeerdijk 2001; Vermimmen 2001	.	.	.	.	.	x	.	.	170.731	518.615
C	Microregio Noordoostpolder		Gehasse 1995; Gotjé 1993; Ten Anscher 2008	.	.	.	.	x	x	x	x		

Table 6.1 (continued): List of literature references.

Zone	Relation to (ground)water table
Dry woodland zone	1 m above
Shrub zone	1 – 0.5 m above
Marsh woodland zone	0.5 – 0.1 m above
Sphagnum-peat zone	0.1 – 0.05 m above
Reed-sedge zone	0.05 m above – 0.5 m below
Reed-rush zone	0.5 m – 1 m below
Open water zone	> 1 m below

Table 6.2: Boolean classification of dominant vegetation zones relative to the water table (source: Peeters 2007).

macroregion) attracted great interest. A relief map of the subsoil at the start of the Holocene was recreated on the basis of geomorphological knowledge and primary coring descriptions.[490] In response to the creation of the Flevoland polder in the previous century, many geomorphological studies were carried out at the mesoregion level, compiling information on the soil structure of the Noordoostpolder, Oostelijk Flevoland and Zuidelijk Flevoland.[491] Archaeological research was finally carried out, with a few exceptions, on a microregional scale, whereby each mesoregion contained an archaeological microregion: the Hoge Vaart-Eem region in Zuidelijk Flevoland, Swifterbant in Oostelijk Flevoland and Schokland-Urk in the Noordoostpolder (fig. 6.2).[492]

Models of groundwater level rise play a key role in palaeogeographical reconstruction. Around the turn of the century, several studies were devoted to developments in the groundwater level curve in various parts of Flevoland.[493] These studies combined with geomorphological data, were used to develop a computer model of vegetation development in Flevoland between 7000 and 4000 BP.[494] The model linked the presence of vegetation zones to the depth of the groundwater level (table 6.2) and also took account of groundwater capillary rise, the accumulation of peat and clay, and a number of geologically determined phases of erosion. The result was a series of maps showing the shift in vegetation zones, in stages of 100 years, between 7000 and 4000 BP (fig. 6.3). The computer simulation shows that an initially wooded, dry landscape was replaced over the course of 3000 years by a landscape with open water and vegetation zones defined by fens and bogs.

490 Peeters 2007.
491 Wiggers 1955; Ente *et al.* 1986; Menke *et al.* 1998 respectively.
492 Gotjé 1993; Ten Anscher 2012.
493 Gotjé 1997a, 1997b, 2001; Makaske *et al.* 2002a, 2003; Van de Plassche 1982; Van de Plassche *et al.* 2005; Roeleveld & Gotjé 1993.
494 Peeters 2007, 56-74.

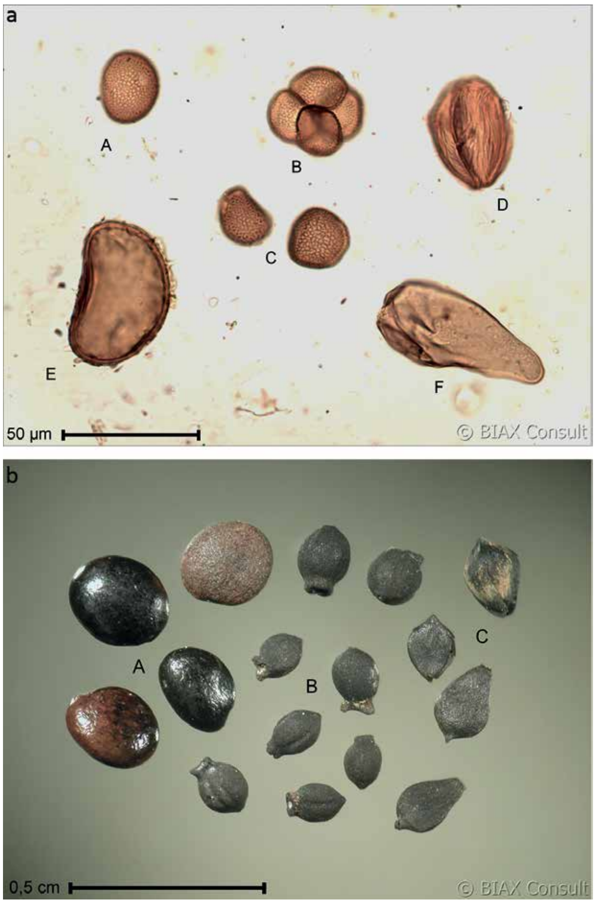

Figure 6.4 Examples of paleobotanical remains that were used to reconstruct the vegetation at the Late Atlantic and Subboreal at Almere-Kotterbos (location 7). a) Pollen of the branched bur-reed type (A), common bulrush (B), lesser bulrush (C), bogbean (D), male-fern / buckler-fern (E) and saw-sedge (F) (photo: BIAX *Consult*); b) Seeds of bogbean (A), saw-sedge (B) and grey club-rush (C) (photo: BIAX *Consult*).

Vegetation models have proved to be a highly useful way of revealing trends and gaining a better understanding of the connection between landscape processes and human activity.[495] Another approach involves data-driven reconstructions of these living landscapes, concentrating on palaeoecological, alongside geomorphological and hydrological data (fig. 6.4). This method is often used to address specific questions, such as: what did the dry coversand regions really look like in the first half of the Holocene? How varied were the marshes and mires in the Late Atlantic and the Subboreal? Was there really no longer any dry land available to humans at the end of the Subboreal?

495 The sensitivity of the model to various parameter settings was recently discussed by Peeters & Romeijn (2016).

Did the lakes that existed in the Subboreal remain in one location, or did they 'wander' around the huge fens and bogs that was Flevoland several thousand years ago?

Information on the palaeovegetation and the fauna associated with it has been drawn from dozens of, often small-scale, palaeoecological studies. Like excavations, these are windows, with certain temporal and spatial limitations (fig. 6.2 and table 6.1), but because there are so many of them, in combination they provide some overall information about the period, beginning in the Late Glacial. For the purposes of this chapter, the palaeoecological data has been translated in a traditional manner into vegetation types. This has the advantage of allowing very small studies with a limited dataset to be included in the overall picture. Because the entire palaeoecological dataset has been reinterpreted, this chapter does not include any summary of previous interpretations. Before turning to the three microregions, a rough outline of landscape development from the Late Glacial to the Subboreal will be presented. The information on these microregions covers much shorter chronological periods, because the palaeoecological information obtained at this scale relates to the archaeological research carried out. For the Hoge Vaart-Eem microregion (Zuidelijk Flevoland), therefore, we primarily have information about the landscape in the period 7000 to 4000 cal. BC,[496] from the Swifterbant microregion (Oostelijk Flevoland) information relates to the period 8300 to 3700 cal. BC[497] and from the Schokland-Urk microregion (Noordoostpolder) to the period 5000 to 800 cal. BC.[498]

6.3 Landscape dynamics in Flevoland

6.3.1 Late Glacial: c. 12,500 – 9800 cal. BC (Late Palaeolithic)

Geology, climate and hydrology

In the Late Glacial, Flevoland was part of a coversand region extending from the southern Netherlands via central and northern Germany into Poland and the southern part of the North Sea basin. The sea level was more than 80 metres below that of today and what is now the southern part of the North Sea was land through which rivers flowed. The Rhine, Meuse and Thames drained in a southerly direction into the Channel River that flowed into the sea to the southwest of what is now Great Britain (Strait of Dover) (fig. 6.5).[499]

There were no major rivers in and around Flevoland. There were, however, local and regional rivers and streams that drained to the west in the summer. In Zuidelijk Flevoland, water drained from the sandy soils of the Utrechtse Heuvelrug ice-pushed ridge, the western Veluwe, and the Gelder Valley, via the Eem and its tributaries. The literature mentions two river systems in Oostelijk Flevoland and the Noordoostpolder.[500] The Hunnepe drained the northeastern part of the Veluwe region and parts of the eastern Netherlands coversand region. The main channel was situated along the southern edge of the Noordoostpolder. In the west it curved to the southwest and flowed through the northwestern part of Oostelijk Flevoland. It is likely that the streams in Oostelijk Flevoland branched onto the main channel of the Hunnepe. The Overijssel Vecht, to the north of the Hunnepe, crossed into the Noordoostpolder to the south of the outcrop of glacial till known as De Voorst, flowing to the north and south respectively of the outcrops of glacial till at Schokland and at Urk. The Overijssel Vecht drained the Pleistocene areas of the eastern part of Gelderland, Overijssel and the southern part of the Drenthe Plateau. It is assumed that the Hunnepe and Overijssel Vecht were connected to each other to the west of Flevoland. The main direction of flow of the Eem in southern Flevoland was to the northwest, and it is not unlikely that this system joined the Hunnepe and the Overijssel Vecht in Noord-Holland in the Early Holocene. Although it would appear that elevation in Flevoland in the Late Glacial generally differed by no more than 20 metres, water will have flowed through a multitude of streams outside the regional river systems mentioned above.

Warm and cold periods alternated in the Late Glacial, in the sequence of the Bølling interstadial, the Older Dryas, the Allerød interstadial and the Younger Dryas. During the cold periods the subsurface was permanently frozen, sand began to drift and the river systems took on a braided character. In both interstadials, vegetation was more abundant, which prevented sand from drifting and caused rivers to meander.[501]

496 Hogestijn & Peeters 2001; Peeters 2007.

497 Cf. Dresscher & Raemaekers 2010; De Moor *et al.* 2009; Hamburg *et al.* 2012.

498 Cf. Bulten *et al.* 2002; Gotjé 1993; Gehasse 1995; Peters & Peeters 2001; Ten Anscher 2012.

499 Cf. Jelgersma 1979; Bourillet *et al.* 2003; Ménot *et al.* 2006.

500 Ente *et al.* 1986; Koopstra *et al.* 1993; Menke & Lenselink 1991; Menke *et al.* 1998; Lenselink & Menke 1995; Wiggers 1955; Vos *et al.* 2020.

501 Nowadays, the Late Glacial climate is defined as being made up of one warm and one cold period (Björck *et al.* 1998, 288). The warm period encompasses the Bølling interstadial, Older Dryas and Allerød interval, and is known as the Greenland Interstadial 1 (GI1: 14,700 to 12,650 years BP). The Older Dryas was a colder period within this interstadial. The cold period that followed, which is often referred to in the literature as the Younger Dryas, is also known as the Greenland Stadial 1 (GS1: 12,650 to 11,500 years BP).

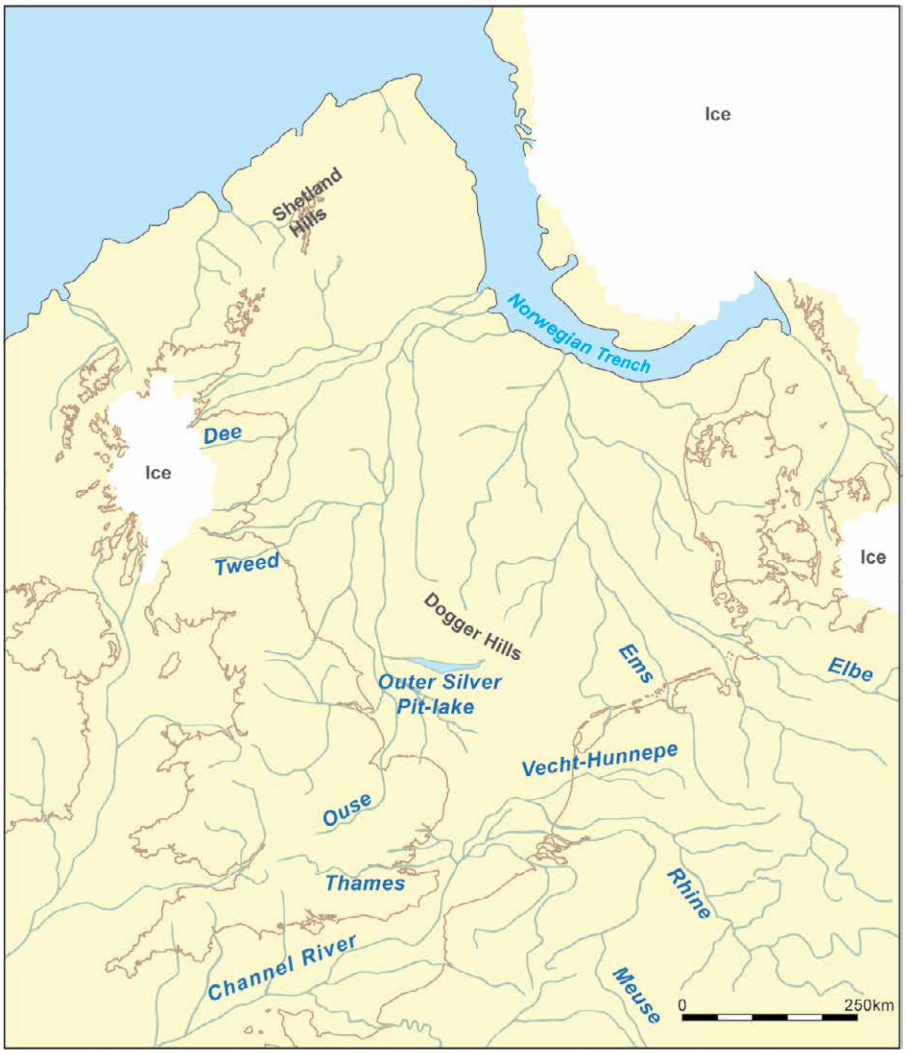

Figure 6.5: The course of the major rivers at the end of the Late Glacial (adapted from Bourillet *et al.*, 2003; Ménot *et al.*, 2006).

Vegetation development in the Late Glacial

Palynological material from nine locations in Flevoland has been analysed (fig. 6.2 and table 6.1). Five of the locations are in Zuidelijk Flevoland, on the edge of the Eem valley, one is on the eastern edge of Oostelijk Flevoland, two are in the northern and one in the southern part of the Noordoostpolder.

The water table in the coversand landscape in the south of the Eem valley rose during the Bølling interstadial (fig. 6.2, table 6.1, no. 17). The soil-forming vegetation that grew here on the coversand transformed halfway through this period into marsh vegetation dominated by mosses and sedges.[502] Thanks to the water-saturated conditions, the moss and sedge did not decay, but accumulated as peat. Unfortunately, no palynological analysis was performed on the peat, so we have no information as to what the Late Glacial landscape would have looked like.

In the low-lying southwest of the polder (fig. 6.2, table 6.1, no. 4) soil formation occurred in the second half of the Allerød when open pine woodland with some birch and juniper developed.[503] Dryas (fig. 6.6), spikemoss (*Selaginella*) and adder's tongue grew in the undergrowth. Although the presence of cold-resistant plants such as dryas and spikemoss suggest the soil contained chalk, the presence of heather and crowberry indicate that there were also soils that were lower in nutrients and more acidic. Willow and species of the sedge family complete the picture of a landscape where variation in relief caused hydrological differences, resulting in a varied vegetation (fig. 6.7).

502 Makaske *et al.* 2002b, 35, 72, 74. Dated to between 12,342 and 12,178 cal. BC (12,240 ± 50 BP, GrA-17230).

503 De Moor *et al.* 2013, 17, 24, 27, 31-32. Soil in coring 7 dated to between 11,446 and 10,904 cal. BC (11,268 ± 118 BP, Ua-44518).

Figure 6.6: Dryas, Greenland (photo: J.A. de Raad).

Figure 6.7: Impression of Flevoland in the second half of the Allerød: a slightly hilly landscape with marshland, birch and pines, Leersumse Veld 2012 (photo: J.A. de Raad).

At the transition from the Allerød to the Younger Dryas, around 11,000 cal. BC, the average summer temperature fell and the climate started to show arctic characteristiscs. Information on the vegetation in this period has been obtained from a location (fig. 6.2, table 6.1, no. 1) to the south of the Eem river valley.[504] The landscape consisted of low sandy ridges with shallow lakes, small rivers and streams in the depressions between them (fig. 6.8). The landscape changed over this period from open parkland vegetation with trees and shrubs into tundra vegetation. All kinds of mosses, grasses and herbaceous plants grew on the dry soils, including mugwort and rockrose, interspersed among low shrubs such as dwarf birch, crowberry and juniper.[505] Trees were scattered around the landscape,

504 Van Smeerdijk 2002. Dated to between 11,053 and 10,772 cal. BC (10,980 ± 60 BP, GrA-17645).

505 In the temperate climate zone juniper develops into a small tree, but in the mountains, on the tundra and on the Scandinavian fells it grows as a small, low shrub, no taller than the low vegetation around it. It is likely that juniper also occurred as a small shrub in the Late Glacial.

Figure 6.8: Impression of Flevoland in the Younger Dryas: a gently undulating landscape with sandy ridges, lakes and rivers. Taymyr Peninsula (Russia), late June 2006 (photo: J.A. de Raad).

including birch and occasionally pine. The small lakes contained algae, species of the Charophytes and cold-resistant water plants. The presence of species of the Charophytes suggests the water was fairly calcium-rich in this period. The marshy low-lying depressions in the landscape were colonised by a wide range of species of the sedge family. However, bogbean, marsh marigold, and species of bedstraw, buttercup, dropwort, meadow rue and mint would have provided a splash of colour in the marshes and along lake shores and streams in the summer. As on the dry soils, shrubs and trees, mainly birch and willow, would have been scattered throughout this marsh landscape. It is not known whether the willow was the short Arctic type, or took the form of shrubs and trees.

At this location the boundary between the Pleistocene sand and the Preboreal peat above it is clear and well-defined. This, combined with the absence of soil formation, has led to an assumption that there was a hiatus in the stratigraphical development.[506] It is possible that the impact of frost or the flow of meltwater during the short summers in the Younger Dryas, eroded the sandy soil that lay at the surface, enabling only short vegetation with shallow roots to grow there.

In the relatively high northern part of the Noordoostpolder a peaty horizon from the Late Glacial was found in the subsurface.[507] This peat appears to have formed in the Allerød and the start of the Younger Dryas. Peat formation is generally an indication of stagnant water. That this relatively high area was so wet during this period was probably due to the presence of an impermeable glacial till layer just below the surface. The poor drainage would have attributed to the wet appearance of this area, certainly in the summer months. Mosses of the Hypnaceae family and all kinds of sedges grew in the fens, with localised occurrences of rushes, bogbean and marsh cinquefoil.

At a certain point, drainage conditions seem to have deteriorated and the fens transformed into shallow lakes in which water plants such as pondweed could grow. These shallow lakes were able to form due to a combination of factors. This development occurred at the transition between the Allerød and the Younger Dryas.[508] As the average summer temperature fell the vegetation changed, giving low-growing herbaceous plants (grasses and sedges) the upper hand, and reducing the abundances of trees and shrubs. There was probably a precipitation excess, the consequences of which could have been enhanced by the decline in vegetation. The combined effects of wind, water and melting ice would have led to the development of open areas with little vegetation, which allowed the sand to drift (Young Coversand). The coversands created barriers that prevented the flow of water. Nor could the water soak into the soil because of the buried glacial till and the permanently frozen soil, causing shallow lakes to form.

At the same time, the Overijssel Vecht was active in the southern part of the Noordoostpolder. This river was either braided or meandering, depending on the climate.[509] The river drained from the east to the west and northwest.

506 Van Smeerdijk 2002.

507 Wiggers 1955, 34. The Late Glacial peat extended as far as the modern villages of Creil and Bant, but has also been found elsewhere in the polder.

508 Wiggers 1955, 37 (no. 37 and 38 in table 6.1 and fig. 6.2).

509 Wiggers 1955, 40-42 (no. 39 in table 6.1 and fig. 6.2).

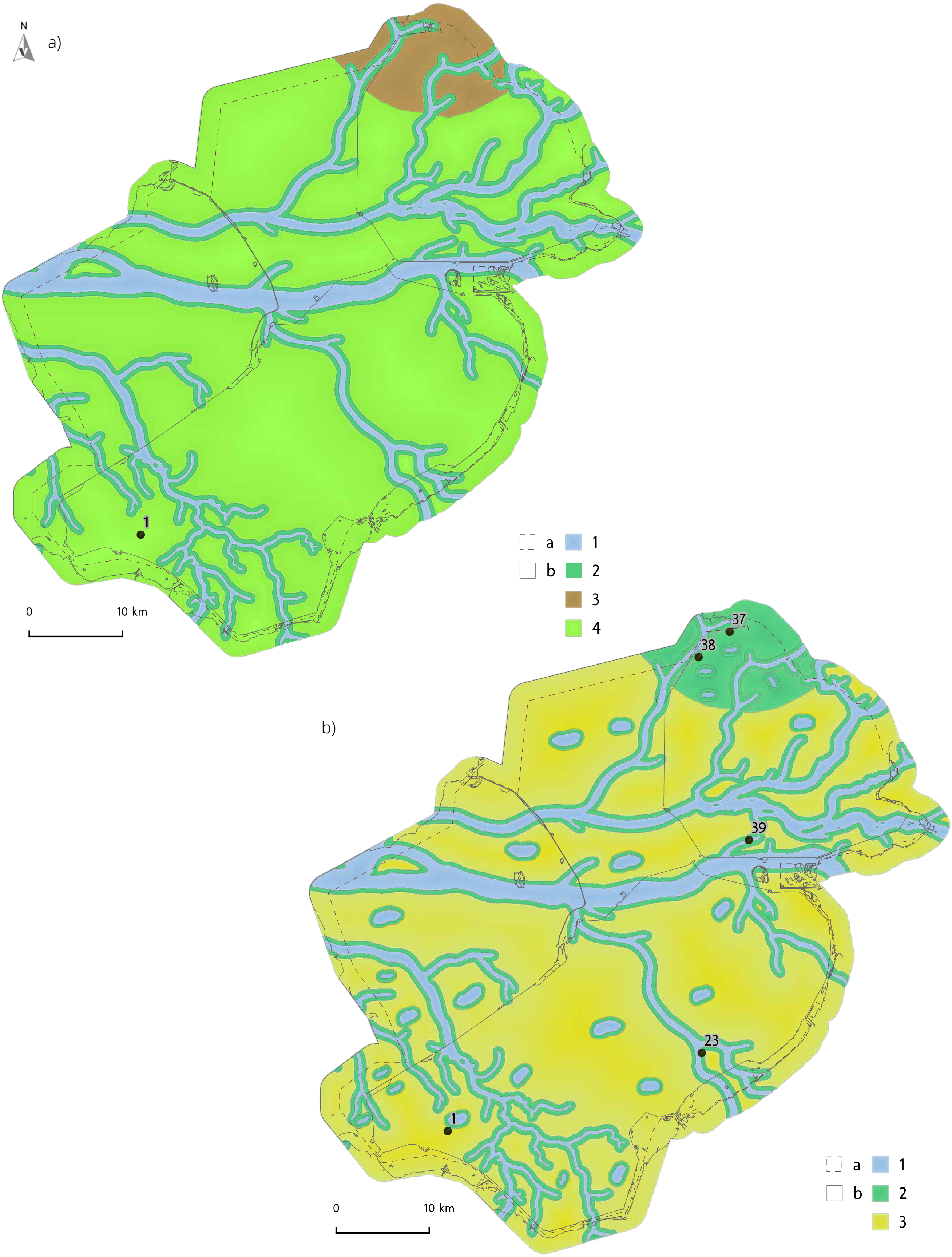
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Figure 6.9a-b (opposite page): Reconstruction of the vegetation of Flevoland in the Allerød (a) and in the Younger Dryas (b) based on palaeoecological information and after the palaeogeographical map of 9000 BC of Vos & De Vries (2018). Legend (a) Allerød: a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers and lakes; 2: marshes and swamps along the rivers with willow, species of the sedge family and herbaceous plants; 3: mires in the north with mosses and species of the sedge family (after Wiggers 1955); 4: open woodland / wooded grassland on dry soils with pine, birch, juniper, species of the heath family, species of the grass family, and other herbaceous species. Legend (b) Younger Dryas: a: topography; b: outline of research area; dot: locations of palaeoecological information (see table 6.1); 1: rivers and lakes; 2: marshes along rivers and lakes and in the north (after Wiggers 1955) with mosses, different small willow species, species of the heath family, species of the sedge family and some herbaceous species; 3: tundra on the drier soils with dwarf birch, (mountain) pine, (small) juniper, species of the heath family and herbaceous species.

Changes in climate also gave rise to different types of vegetation. Outside the Overijssel Vecht river basin, however, dry soils were present on some scale, covered with grasses, mugwort and species of the heath family. In the Allerød there was a much higher proportion of birch and pine in the vegetation than in the Younger Dryas. The subsurface in the southern part of the Noordoostpolder, also became unstable during the Younger Dryas due to the absence of robust vegetation. As a result, the existing marshy depressions disappeared beneath a layer of loam on top of which sandy river dunes began to form.

As in the northern part of the Noordoostpolder, the Younger Dryas also saw the stagnation of water flow in the higher-lying eastern part of eastern Flevoland.[510] Shallow, relatively nutrient-rich lakes formed in which algae, spiked water-milfoil, pondweed and water-crowfoot grew. The surface of the water would have been covered with the floating leaves and flowers of white and yellow water lilies in summer. Around the lakes there were dry soils showing evidence for the same type of vegetation found elsewhere in Flevoland: open vegetation with grasses, mugwort, rockrose, juniper and species of the heath family, including crowberry. Tree species like birch and pine would have been scattered about the landscape.

In conclusion, the Late Glacial, a period spanning some 2700 years, was characterised by the alternation of warm and cold periods. Most of the information we have for Flevoland comes from the Allerød and Younger Dryas (fig. 6.9), which both lasted roughly 1000 years. The landscape of Flevoland was remarkably wet in this period. Extensive marshland existed during the Allerød. Due to the deposition of Young Coversand and a frozen subsurface, this marshland developed into a series of interlinked lakes during the Younger Dryas. More or less the same cold-resistant plant species grew in the area in both periods, although the vegetation structure and proportional composition of the species changed. In the Allerød the dry soils were covered with open woodland consisting of birch and pine, with grasses and herbaceous plants in the undergrowth. In the Younger Dryas the birch and pine population declined sharply, and at a certain point only woody shrub-like vegetation would have grown there, including dwarf birch, mountain pine and the willows that grow nowadays in Arctic regions (Arctic willow, dwarf willow, net-leaved willow and polar willow). The landscape was no longer home to any of the tree species, and parts of the ground were devoid of vegetation, or covered with herbaceous vegetation consisting of grasses and sedges.

510 De Jong 1974, Biddinghuizen profile (no. 23 in table 6.1 and fig. 6.2).

6.3.2 Preboreal: c. 9800 – 8200 cal. BC (Early and start of Middle Mesolithic)

Geology, climate and hydrology

After the Younger Dryas the average summer temperature rose to between 15 and 20°C, heralding the start of a warm period, the Holocene, in which several phases have been distinguished on the basis of the predominant climate conditions and the occurrence of certain plants. In the first phase, the Preboreal, large quantities of water were stored in land ice. The sea was far away, which meant a continental climate prevailed, with cold winters and hot, dry summers. As in the period discussed above, Flevoland was still part of an extensive coversand region and, although the temperatures were similar to those of today, many cold-intolerant plants (and animals) were still confined to southern Europe.

It could have been a combination of landscape and climatological factors that caused the marshes and lakes of the Younger Dryas to make way for a landscape more accessible to humans. The frozen subsurface thawed, which lead to improved water drainage. It is also likely that, as a result of the higher temperatures, the rate of evapotranspiration exceeded the precipitation in summer, as is generally the case today. As the temperature rose, the biomass of the vegetation increased. The Preboreal vegetation will therefore have required more water than the tundra vegetation of the Younger Dryas. Influenced in part by the more robust vegetation, the shallow, braided rivers transformed into meandering rivers that cut into the landscape. These rivers drained water from large areas of the Drenthe Plateau and the coversand regions of the eastern and central Netherlands, flowing via low-lying Flevoland to the west and northwest (fig. 6.1a).

Vegetation development in the Preboreal

Botanical remains dating to the Preboreal have been analysed from nine locations in Flevoland (fig. 6.2, table 6.1): five from southern Flevoland along the edge of the Eem valley, one from the eastern edge of Oostelijk Flevoland and three from the Noordoostpolder.[511]

Information from Zuidelijk Flevoland comes once again from south of the Eem valley, from an area with low coversand ridges alternating with valleys (fig. 6.2, table 6.1, no.1).[512] Two ^{14}C dates taken from the peat base in one of these valleys show that it developed in the Preboreal.[513] The peat may have accumulated within a lake environment.[514] Water plants like alternate-flowered water-milfoil and species of pondweed were gradually replaced in the Preboreal by fen vegetation featuring reeds, various sedge species and other herbaceous plants. The botanical remains show evidence for several species of marsh and water plants. Some of these would have preferred water with high levels of oxygen in relatively nutrient-poor conditions, but some species also indicate conditions with higher nutrient levels. It has been assumed, on the basis of the composition of plant remains, that nutrient-poor rainwater accumulated on top of relatively nutrient-rich groundwater which contained minerals from a deeper loam layer.[515] Birch was initially dominant in the dry regions of the landscape. The remains of seeds and catkins clearly show that this was downy or silver birch, the two native tree species within the birch genus. The birch grew with pines in open spaces featuring sea-buckthorn, juniper, crowberry, grasses and other herbaceous plants in the undergrowth. In the course of the Preboreal the proportion of birch declined in favour of pine, as was also the case elsewhere in the Netherlands.[516] Two woody taxa have not yet been mentioned: willow and poplar. The willow taxon probably include shrub species or species of small trees. The poplar may have been aspen, a tree species known to have grown in the Late Glacial in, or on the edge of marshes and swamps.[517]

Palynological material from a buried Pleistocene soil just to the east of this location was also analysed (fig. 6.2, table 6.1, no. 3).[518] A pine woodland grew on the coversand here.[519] This must have been a fairly dense woodland on dry coversand, as barely any remains of herbaceous plants or indicators of water have been found. However, heather, male-fern / buckler-fern and stag's-horn clubmoss probably grew in the undergrowth (fig. 6.10). Male-fern / buckler-fern include various fern species that are specific to very different types of locations. In peat, for example, remains of marsh fern, crested buckler-fern and/or narrow-buckler fern have been found. It is likely that other fern species were found here, as the palynological material comes from a coversand soil. Given the evidence for relatively dry pine woodland, it could be male-fern or broad buckler-fern. These species are still commonly found in woodland on sandy soil. Stag's horn clubmoss in combination with heather suggests there were glades in the woodland. This clubmoss species prefers sandy soil with good drainage but that does not dry out.[520]

That pine was a dominant component in the vegetation can also be assumed by the discovery of pine charcoal in the coversand to the east of Hoge Vaart (fig. 6.2, table 6.1, no. 21). Charcoal dating from the second half of the Preboreal has been found in the coversand in the most southwesterly part of Zuidelijk Flevoland (fig. 6.2, table 6.1, no. 4).[521] The palynological material suggests that at least some of the charcoal is of a more recent date and comes from the younger peat cover. This may indicate the landscape in this area was covered in pines with heather and crowberry undergrowth, as was common in the second half of the Preboreal.

Palynological material found in peaty sandy soil at the Hoge Vaart-A27 site (fig. 6.2, table 6.1, no. 13) in the riparian zone of the Eem probably dates from the Preboreal.[522] In the Preboreal, the bank of the river was saturated with water at this spot, so organic material did not decay completely. The palynological analysis has revealed that willows, grasses, sedges and bulrushes grew on the riverbank and that birch and pines grew on drier soils, possibly with heath in the undergrowth.

511 Bunnik & Verbruggen 2011; Gotjé 2001; De Jong 1974; Kooistra 2012a; Van Smeerdijk 2002; Wiggers 1955, 47-51.

512 Van Smeerdijk 2002.

513 Van Smeerdijk 2002. The dates are 10,050 ± 50 BP (GrA-16838) and 10,010 ± 50 BP (GrA-16753).

514 In the geological terminology of the Netherlands peat accumulated during the Holocene is attributed to the Nieuwkoop Formation (*Formatie van Nieuwkoop*).

515 Van Smeerdijk 2002, 19.

516 E.g. Hoek 1997a, 1997b.

517 Van Smeerdijk 2002, based on Hoek 1997b, 92.

518 Bunnik & Verbruggen 2011.

519 In coversand soils palynological material migrates downwards from the surface (cf. Dimbleby 1985; Havinga 1963, 1974; Van Mourik 2001; 2003; Van Mourik *et al.* 2010, 2011, 2012; Van Smeerdijk 1989). Roughly speaking, the oldest material will lie deepest in the soil. The level at which it is found does not therefore necessarily represent the level at which the material was deposited. This contrasts with palynological material in peat and clay, which was deposited at the depth at which it is found.

520 Weeda *et al.* 1985, 15.

521 De Moor *et al.* 2013, 16, 25. Dated on basis of charcoal to between 9194 and 8296 cal. BC (9389 ± 172,Ua-44511).

522 Gotjé 2001, 23, 42. The Eem2 core.

Figure 6.10: Stag's-horn clubmoss, a common species of clubmoss on dry Pleistocene coversands (photo: J.A. de Raad).

The lake in the higher-lying eastern part of Oostelijk Flevoland disappeared in the course of the Younger Dryas and Preboreal as sedge vegetation developed (fig. 6.2, table 6.1, no. 23).[523] The peat that accumulated from this vegetation also contained pollen from vegetation in the vicinity of the fen. This suggests that pine woodlands grew here on the dry soils in the second half of the Preboreal. This woodland appears to have been dense initially, but the presence of hazel and birch pollen suggests that there must have been open patches, possibly at border zones between the dry coversands and the sedge fens.

After the Younger Dryas, the low tundra vegetation on the coversands in the northern part of the Noordoostpolder seem to have become colonised by birch and pine, and sometimes also willow.[524] The coversand is humic here, which could be an indication of the continued presence of stagnating groundwater. Reed fens with large quantities of sedge species were to be found in the lowest-lying parts of the coversand region (fig. 6.2, table 6.1, no. 40). Stagnating water led to the development of peat, which trapped pollen from the surrounding vegetation. As in many other parts of The Netherlands, pines dominated the woodland in the drier parts of the landscape at the end of the Preboreal.[525]

The age of the peaty and sandy deposits in the southern Noordoostpolder is not known for certain.[526] Peat found beneath a river dune (fig. 6.2, table 6.1, no. 39) has been dated to between 10,990 and 9444 cal. BC. This would have accumulated in the Younger Dryas or the first half of the Preboreal.[527] However, the pollen spectrum found would appear to be more consistent with vegetation from the final phase of the Allerød, when the amount of pine pollen declined and birch pollen increased.

In the initial period of the Holocene the subsurface of Flevoland was drier than it had been for a long time. In the course of the Preboreal, sand ceased drifting as rising temperatures caused an expansion in vegetation which held the subsurface more firmly in place. The fact that river dunes formed along the Hunnepe and Overijssel Vecht during this period suggests that sand was still drifting along the rivers, however (fig. 6.11).[528] The herbaceous, grass- and sedge-rich tundra vegetation on the coversand ridges and flanks made way for a wooded landscape with birch and pines. Pine woodland came to dominate during the Preboreal. Pines produce large amounts of pollen, this suggests that the woodland may not have been as dense as one might assume on the basis of the high percentages of pine pollen recovered. In a natural situation, pines grow in open woodlands, as they need light to survive. The presence of birch and hazel, which also require plenty of light, suggests that the woodland that did form was not dense.[529] Even in the most recent period of the Preboreal, in which the palynological signal for pine woodland is

523 De Jong 1974.

524 Wiggers 1955, 50.

525 Wiggers 1955, 47-48.

526 Wiggers 1955, 40-42 (plot E155). Interpretation of the diagrams published by Wiggers is difficult because the dates ascribed to the Late Glacial and Early Holocene periods have changed since the 1950s.

527 Wiggers 1955, 42. Dating: 10,500 ± 280 BP (GRO 375) calibrated using OxCal v4.2.3 (Bronk Ramsey 2013) and the IntCal13 atmospheric curve (Reimer *et al.* 2013).

528 Cf.. Wiggers 1955, 38-42.

529 Our image of pine woodlands is influenced by commercial forestry, in which trees of equal age are planted equidistant, and as close to each other as possible.

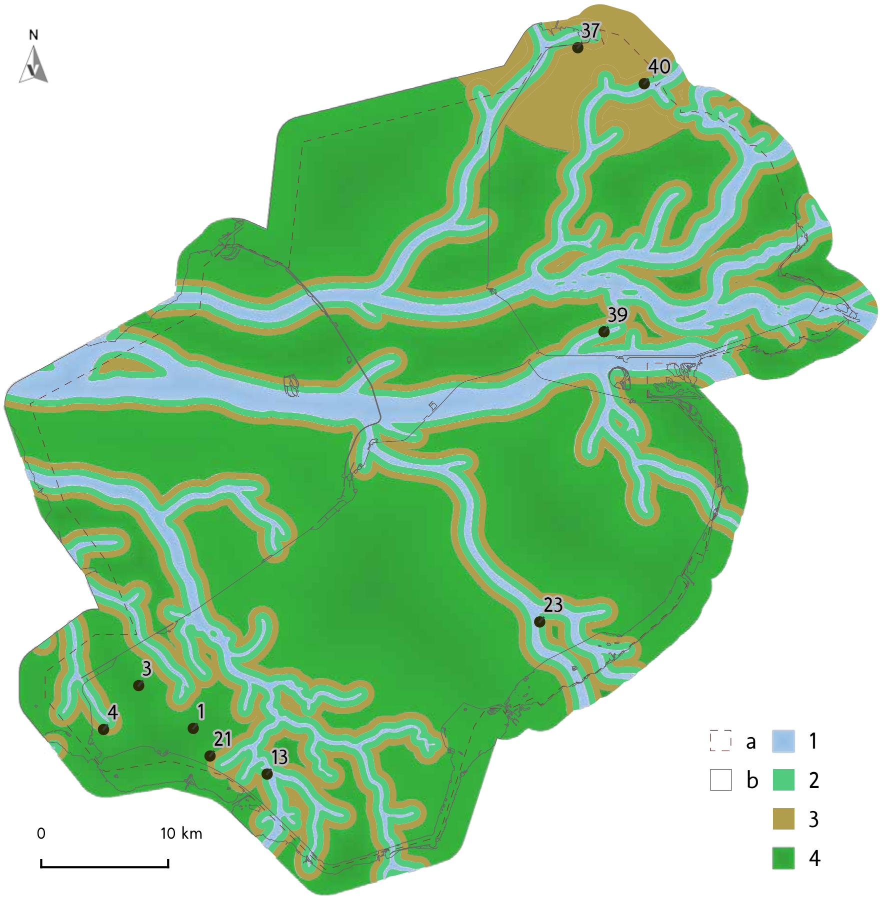


Figure 6.11: Reconstruction of the vegetation of Flevoland in the Preboreal based on palaeoecological information and after the palaeogeographical map of 9000 BC of Vos & De Vries (2018). Legend: a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers; 2: marshes and swamps along the rivers with willow, poplar, species of the sedge family and species of the grass family; 3: mires in river valleys and in the north with species of the sedge family; 4: open woodland on the dry soils with pine, birch, species of the grass family, species of the heath family, and in the second half of the Preboreal also hazel.

strongest, heather and stag's-horn clubmoss still occurred locally. These two species would have grown in sunny or semi-shaded spots.

Fens with sedges and reed formed in the lowest-lying valleys in the coversand landscape, such as along the Eem and in the northern Noordoostpolder. Here, and elsewhere along rivers and the edges of low-lying valleys, grew willows and probably also aspen.

6.3.3 Boreal: 8200 – 7000 cal. BC (Middle Mesolithic)

Geology, climate and hydrology

During the Boreal there was barely any change in the geological landscape of Flevoland. The ice caps of northern and central Europe continued to melt however, causing the lowest coversand regions of the North Sea basin to disappear under water. Flevoland was not yet affected by the rising sea level and, as in previous periods, was situated in an extensive coversand region. The climate therefore still had a fairly continental character.

Vegetation development in the Boreal

Botanical remains found at eleven sites and dating from the Boreal have been analysed: four from Zuidelijk Flevoland, two from Oostelijk Flevoland and five from the northern Noordoostpolder (fig. 6.2, table 6.1).

During this period, the mire in a low-lying valley to the south of the Eem (fig. 6.2, table 6.1, no. 1) transformed into land.[530] This process was instigated by reed and species of the sedge family. This vegetation may have developed so

530 Van Smeerdijk 2002.

rapidly that it caused the mire to dry out. The higher sandy soils around the valley were home to pine trees and other vegetation during this period. Given the pollen spectrum which includes birch, juniper and a small amount of heath, this could have been open or semi-open woodland, rather than expanses of dense pine woodland. The large quantity of pollen recovered indicates, however, that pine was the most predominant tree species on the dry soils. This may have reduced the amount of water flowing into the valleys, and could have been a factor in the drying out of the mire. Unlike the many deciduous trees in a temperate climate zone, pines grow all year round and therefore require water all year round.[531] An increase in the number of pines in the landscape would therefore have led to the ground becoming drier, if the supply of water remained constant. The large quantities of pine pollen, as well as the clear presence of pollen from cold-intolerant deciduous trees are typical of the Boreal. Cold-intolerant deciduous trees had reached the Netherlands by this time and had established themselves in the vegetation.[532] In the swampy hollows of the Eem valley willows were joined by alder in this period. Woodland on drier soils was more varied, with hazel, oak, elm and lime.

At the same time, the coversand in the far southwest of Zuidelijk Flevoland (fig. 6.2, table 6.1, no. 4) still supported open pine woodland in which the first deciduous trees established themselves.[533] Pine also appears to have dominated the vegetation in the riparian zone of the Eem in the higher-lying southern area of Zuidelijk Flevoland (figure 6.2, table 6.1, no. 9), as suggested by the discovery of a pine log and pine cones in a peaty layer (fig. 6.12).[534] Just to the east, at the end of the Boreal, peat formed from the decayed remains of sedges as well as other fen vegetation was laid down in a coversand hollow (fig. 6.2, table 6.1, no. 21).[535] The fact that species of the sedge family are the ones most commonly identified in the fen vegetation suggest relatively nutrient-poor, possibly acidic soil conditions when peat formation began. Pine, birch, oak, hazel and elm all grew in the vicinity of the mire. Again, there are indications of heath in the undergrowth.

Three layers containing palynological material found in the east of Zuidelijk Flevoland and dating to the Boreal were analysed in the mid-20th century (fig. 6.2, table 6.1, no. 24).[536] Pines and an undergrowth of ferns and stag's horn clubmoss appear to characterise the vegetation here in this period. The presence of hazel, birch and oak again suggests an open landscape with trees, open woodland or woodland with open patches. In the north of Oostelijk Flevoland information on the vegetation comes from the analysis of charcoal from 14 pit hearths dug by the Mesolithic inhabitants (fig. 6.2, table 6.1, no. 25).[537] The charcoal recovered from the hearths was indisputably the product of human activity but, if the wood had been deliberately selected for use, it could give a distorted picture if used as an indicator of the woody vegetation growing in the Boreal. It is, however, very likely that the wood was gathered in the vicinity of the Mesolithic camp. As could have been expected on the basis of palynological analysis of samples from elsewhere in Flevoland, pine was the species most strongly represented. As well as charcoal, carbonised fragments of pine cone scales have regularly been found. The oldest pit hearths contained only pine. The hearths dating from 7600 cal. BC onwards contained other species: birch, oak, alder, elm and willow. Carbonised remains of hazelnuts have also been found. Charcoal of species of the Malaceae subfamily cannot be determined with a high degree of accuracy, but may be from crab apple, mountain ash, hawthorn or wild pear. Again, a picture emerges of a landscape featuring lots of pine, but with enough room for other species of tree that needed lots of light. In summary, therefore, an open landscape with plenty of trees, but not dense pine woodland.

The build-up of peat that started in the Preboreal continued in the northern Noordoostpolder (fig. 6.2, table 6.1, no. 40-41).[538] The wet low-lying depressions in the landscape became overgrown with vegetation that included reed, sedge, saw-sedge, bogbean, marsh cinquefoil and ferns. Vegetation such as this indicates the

Figure 6.12: Seeds and a cone of Scots pine (*Pinus sylvestris*) found in a channel of the Eem at Hoge Vaart-A27 (location 8) (photo: Cultural Heritage Agency of the Netherlands).

531 Each type of vegetation has its own water requirements. Herbaceous vegetation generally transpires less water and therefore needs less than woodland. The water requirement or level of transpiration in a woodland depends on the type of trees growing there.

532 Janssen 1974, 55-57; Van Geel *et al.* 1981, 411; Hoek 1997a, 21.

533 De Moor *et al.* 2013. No purely Boreal palynological samples were analysed, as all appear to have been contaminated with material from more recent periods (see 23, 25, 28-29, 32).

534 Spek *et al.* 2001a, 2001b.

535 Bos & Verbruggen 2012.

536 Havinga 1963, 75-77.

537 Kooistra 2012c.

538 Wiggers 1955, 47-49.

Figure 6.13: Impression of Flevoland in the Boreal with open coniferous woodland on the highest spots in the landscape and fen meadows and marshes at the contact zone with water. Omolon river area (Russia), July 1993 (photo: J.A. de Raad).

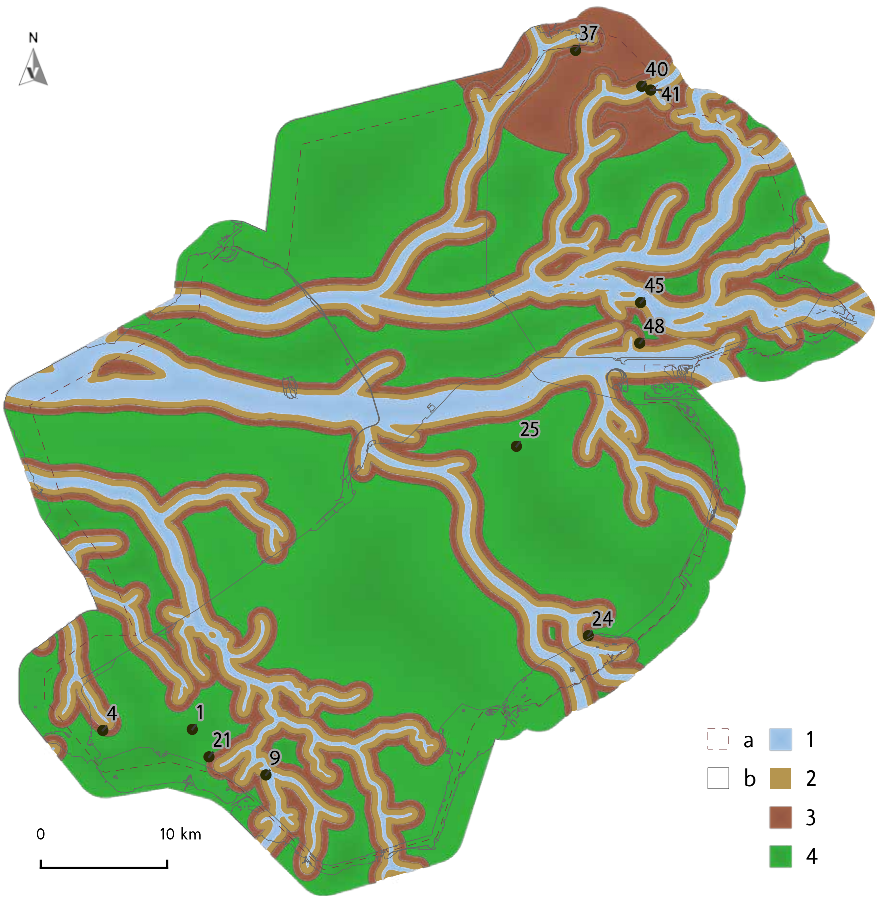


Figure 6.14: Reconstruction of the vegetation of Flevoland in the Boreal based on palaeoecological information and after the palaeogeographical map of 9000 BC of Vos & De Vries 2018. Legend: a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers; 2: marshes and swamps along the rivers with willow, poplar, alder, species of the sedge family and species of the grass family; 3: mires in the river valleys and in the north with species of the sedge family; 4: open woodland on the dry soils with pine, birch, hazel, oak, elm, (lime), species of the grass family, species of the heath family.

presence of a moderately nutrient-rich soil. The presence of saw-sedge indicates the availability of calcium. The dry coversands supported pine, birch, hazel and oak, as elsewhere. Finally, a palynological sample from a humic coversand soil in the far north of the Noordoostpolder (fig. 6.2, table 6.1, no. 37) indicates that the location itself was fairly wet in the Boreal, as evidenced by the presence of species of the sedge family, alder and willow. The dryer soils in the vicinity were however dominated by pine, birch, oak and hazel.

As in the Preboreal, the Boreal landscape would have been quite accessible to the inhabitants. It seems there were fewer mires in the coversand hollows. Many of these mires may have dried up during this period, causing the peat to partially degenerate and decay. It is not clear whether this drying out can be explained solely by climatological factors (temperatures higher than in the Late Glacial and a more continental climate than at present). It is, however, clear that there was an abundance of pine trees in the dryer parts of the landscape, and these would have drawn more water from the surrounding environment than other sorts of woody vegetation (fig. 6.13).

It has been suggested in the past that the dry coversand areas of Flevoland were covered with dense pine woodlands, but this was not in fact the case, although pine was certainly the most dominant tree species. The landscape of the dry coversands must have been much more open, as suggested by the presence of other trees and shrubs that required lots of light, and the widespread evidence for low vegetation featuring ferns, stag's head clubmoss and heath (fig. 6.14).

As was the case elsewhere in the Netherlands, an increasing number of cold-intolerant deciduous trees and shrubs began to establish themselves among the vegetation in the course of the Boreal.

6.3.4 Early Atlantic : 7000 – 6000 cal. BC (Middle and early Late Mesolithic)

Geology, climate and hydrology

The Early Atlantic was the last period in which Flevoland formed part of the relatively high-lying coversand regions through which regional rivers drained water from the Utrechtse Heuvelrug ice-pushed ridge, the Veluwe, eastern Gelderland, Overijssel and the southwestern part of the Drenthe Plateau. Whilst Flevoland was at the centre of an extensive coversand region during the Boreal, in the Early Atlantic it came to lie on the western edge of the region. The infilling of the North Sea basin created an Atlantic climate, with less cold winters and less warm and dry summers. The general consensus regarding the entire Atlantic is that annual precipitation levels were higher than in previous periods, and that the average annual temperature reached its highest level for the entire Holocene (disregarding current temperature increases).

Although many parts of Flevoland still had the typical appearance of a dry coversand area, the hydrology and the composition of the surface water changed. Initially, only rivers transported clay and relatively nutrient-rich water in from the wider region. The vegetation in the dry parts of coversand ridges had to survive mainly on rainwater containing few nutrients. The rising sea level prevented the free drainage of fresh water. This effect in turn caused the water level in Flevoland to rise. Groundwater that had been in contact with old river deposits was relatively rich in nutrients, and the rise in the water level meant that, at a certain point, the groundwater became accessible to the vegetation. The higher moisture levels in the soil and the availability of water containing these higher nutrient levels caused the composition of the vegetation to change. Freshwater marshes and mires developed in places where the groundwater came to the surface, such as in river valleys, the western part of Flevoland and in low-lying parts of the coversand landscape.

Vegetation development in the Early Atlantic

Botanical material possibly dating from the Early Atlantic was analysed from twelve locations: four locations near the Eem in Zuidelijk Flevoland, five in Oostelijk Flevoland and three in the northern Noordoostpolder (fig. 6.2, table 6.1).[539] Plant remains from coversand soils were analysed from most of these locations. A few samples came from a channel fill, with analysed samples from peat deposits coming only from the south of Zuidelijk Flevoland and the northern Noordoostpolder. A large number of observations regarding the composition of the Atlantic peat exist for the Noordoostpolder. These date from the first half of the twentieth century, just after the polder had been reclaimed.[540]

One of the peat locations analysed in Zuideliijk Flevoland was situated in the valley mentioned previously, to the south of the Eem valley (fig. 6.2, table 6.1, no. 1). The picture that emerges from the botanical remains is one of vegetation growing in nutrient-poor soil. The drier areas in the vicinity were covered with wooded parkland-like vegetation, featuring hazel and oak on a nutrient-poor soil. The peat appears to be developed from bog-mosses and other moss species. In combination with the remains of hare's-tail cottongrass and heather, this suggests an environment resembling bog. Birch seeds and alder pollen show, however, that this was not an extensive area. Birch, specifically downy birch, and heather are known to grow

539 Bos & Verbruggen 2012; Havinga 1963; Kooistra *et al.* 2009; Kooistra 2012a, 2012b; De Moor *et al.* 2009; Van der Linden 2010; Van Smeerdijk 2002; Wiggers 1955.

540 Wiggers 1955, 51-53.

Figure 6.15: Impression of an open landscape with heathland, where pine, birch and oak grew. Edense hei (te Netherlands), August 2015 (photo: BIAX *Consult*/L.I. Kooistra).

in relatively dry mesotrophic fens, mainly on slightly ripening peat. Alder, on the other hand, is a tree found in eutrophic fens and carrs. It can grow happily with the foot of its trunk in water. Since only alder pollen (no seeds, no wood) has been found, it can be assumed that the wetter, more nutrient-rich landscape lay further away. The seeds of birch and heather, in contrast, suggest there was relatively dry, nutrient-poor peat in the immediate vicinity, though we cannot rule out the possibility that the birch pollen is from a close relative of downy birch – silver birch – which prefers dry, nutrient-poor positions on coversand. Given that there was open woodland, including lots of hazel, growing on coversand, it is likely that the heather was part of the undergrowth.

It is not clear how the vegetation in southwest Zuidelijk Flevoland developed in this period, since the palynological material is mixed (fig. 6.2, table 6.1, no. 4).[541] Large quantities of heather pollen have been found in the sandy peat deposited on the southern banks of the Eem (fig. 6.2, table 6.1, no. 6).[542] The peat (containing no sand) found above this dates to between 5800 and 5662 cal. BC.[543] We can deduce from this that the sandy peat therefore accumulated slightly earlier, possibly during the transition from the Early to Middle Atlantic. The presence of heather pollen together with pollen from birch, hazel, oak, pine and elm makes it likely that in this period the dry coversands were covered with heathland on which grew hazel, birch and, to a lesser extent, oak, pine and elm. This evokes similarities with today's parkland-type heathlands on nutrient-poor, acidic sandy soils (fig. 6.15). In the period in question the sampling point itself was situated in a water-saturated landscape, as evidenced by the sandy peat and the waterlogged plant remains it contained. The main evidence for vegetation are the reed remains and a high proportion of alder pollen. Carr may have developed at this spot, largely comprising alder, with reed as undergrowth. Dense alder carr does not normally admit much pollen from plants growing on dry soils. However, 76 heather pollen grains and 65 hazel pollen grains were counted for every 100 alder pollen grains, so clearly the alder did not form a complete physical barrier to pollen from the surrounding environment.[544] This means that though there was a lot of alder pollen, there were not so many alder trees that they formed dense woodland. The presence of sand in the peat in fact suggests an open vegetation including alder, rather than dense woodland.

Further inland, pine charcoal was found in the coversand (fig. 6.2, table 6.1, no. 21).[545] It was ^{14}C-dated, and a calibrated age of 6648 to 6482 cal. BC established.[546] A pollen sample from the coversand soil at this location gave high pollen percentages for heather, hazel, alder and willow.[547] Pine and oak were found in small proportions. The low percentage of pine makes it likely that the pollen reflects a vegetation younger than the above date from the middle of the Early Atlantic . However, the possibility that the pine

541 De Moor *et al.* 2013.
542 Van der Linden 2010.
543 6847±32 BP (KIA-43244).
544 An upland tree pollen sum was used (pine was not included as upland tree pollen). The percentages of other species, such as alder and heather, were calculated on the basis of this pollen sum.
545 Kooistra 2012a.
546 Opbroek & Lohof 2012, 55.
547 Bos & Verbruggen 2012, 39, 42. The reference is to the results from the pollen sample from the coversand ridge, pit 4 (AO-515).

charcoal is the result of human selection cannot be ruled out, despite the fact that little evidence of human activity has been found at this location. Whether the palynological material formed in the Early Atlantic, at the transition from the Early to the Middle Atlantic, or in the Middle Atlantic, it is clear that there was no dense deciduous woodland there at that time. Again, there was dry heathland with hazel, oak, birch and perhaps a few pines. Alder and willow grew in the lower-lying parts of the landscape.

The botanical material from a channel deposit in the north of Oostelijk Flevoland is difficult to interpret (fig. 6.2, table 6.1, no. 34).[548] The material originates from washed out deposits, which means it could be a mix of material from different periods and different geographical origins. A podzol was analysed just to the east of this sample location (fig. 6.2, table 6.1, no. 35).[549] The dry soils appear to have supported open oak woodland with hazel. Birch, pine, elm or lime may have grown here and there, although the latter is probably not all that likely. Lime needs relatively nutrient-rich, calcareous soil, and the undergrowth of this open woodland included heather and possibly also crowberry – indicators of dry, nutrient-poor, acidic sandy soils. Furthermore, there is clear evidence of bracken. Nowadays, this fern species indicates old woodland soils low in calcium and nutrients, and the same would have been the case in the past. At the sample location itself wet conditions predominated, as evidenced by the presence of alder pollen, and also of pollen from several aquatic and marsh plants such as pondweed, bogbean and possibly celery. There is no ^{14}C date that can give a definitive age for the botanical material, but the researchers assume the Middle Atlantic, given the pollen spectrum.[550] A dating in the Early Atlantic period cannot however be ruled out. A Mesolithic site was excavated close to this location (Dronten-N23, fig. 6.2, table 6.1, no. 25). Charcoal from three pit hearths dating to the Early Atlantic shows a broad spectrum of tree species, with barely any pine.[551] The variety of species in the charcoal suggests that the inhabitants of the site did not select specific wood species, but simply gathered what was available nearby. This reinforces the idea that the pollen spectrum at Location 35 dates from the Early Atlantic.

While pine had disappeared from the landscape in the relatively low-lying coversand area around Locations 25 and 35 by halfway through the Early Atlantic, it appears that it was still prominent on the higher coversand in the east of Oostelijk Flevoland (fig. 6.2, table 6.1, no. 31).[552] Several dozen Mesolithic pit hearths have been excavated in this area. On the basis of the analysis and ^{14}C dating of charcoal from a number of the pits, a date in the first half of the Early Atlantic can be established. The pits contained almost exclusively pine charcoal and carbonised pine cone scales. Only the most recent pit hearth (6360-6070 cal. BC; 7350 ± 40 BP) contained a few pieces of oak charcoal.[553] We should however bear in mind that the picture may be distorted as a result of selective wood use.

The palynological material from another location in the east of Oostelijk Flevoland (fig. 6.2, table 6.1, no. 24) was not ^{14}C dated. It is therefore not clear whether any palynological information from the Early Atlantic has been preserved.[554] If pine continued to grow on the dry coversands of Flevoland, it could be that some of the palynological data traditionally attributed to the Boreal due to a dominance of pine actually date from the Early Atlantic. Interestingly, heath barely played any role here in the transition from a landscape dominated by pine to a landscape of largely deciduous woodland. Perhaps the soil contained more nutrients here, or the hydrology was different.

The peat in the northern Noordoostpolder became less nutrient-rich in the course of the Boreal, or perhaps the Early Atlantic – there is no ^{14}C date available (fig. 6.2, table 6.1, nos. 40 & 41).[555] The peat initially consisted of reed, remains of species of the sedge family, marsh cinquefoil and bogbean. At the start of the Atlantic, probably in the Early Atlantic, the reed disappeared from the fen and a transitional mire with mesotrophic sedge peat developed. The pollen shows that pine was gradually making way for hazel, oak and birch in the vicinity. Interestingly, there was an increase in heath pollen at the same time, making it likely that heath provided ground cover on the dry coversands in the area. A mesotrophic peat also developed at a nearby location (fig. 6.2, table 6.1, no. 37) on the humic sand from the Boreal, because of an increase in birch pollen right from the start of the peat formation process.

During the Atlantic – it is not clear exactly when – peat started to develop in several of the lower lying areas in the coversands of the Noordoostpolder.[556] In almost all cases this was oligotrophic peat, that is peat which formed in a very wet, acidic, nutrient-poor environment. In the western Noordoostpolder peat that developed from a sedge mire has been found on top of the coversand. Given the elevation of this coversand, this peat probably did not accumulate until the start of the Late Atlantic, from 5000 cal. BC onwards.

548 De Moor *et al.* 2009, 67-68.
549 De Moor *et al.* 2009, 72-74.
550 De Moor *et al.* 2009, 74.
551 Kooistra 2012c.
552 Kooistra *et al.* 2009.
553 Poz-29482.
554 Havinga 1963, 75-77.
555 Wiggers 1955, 48-49.
556 Wiggers 1955, 51.

Figure 6.16: Impression of open oak woodland, Mijnweg (the Netherlands), July 2010 (photo: J.A. de Raad).

No Atlantic woodland in Flevoland in the Early Atlantic

In considering the relatively scarce data from the Early Atlantic, it is clear that the vegetation in Flevoland developed in a slightly different way than was previously thought. The generally accepted picture is that the Boreal pine woodland was replaced in the Atlantic by a mixed deciduous woodland that included elm and lime.[557] This would indeed have occurred in the nutrient-rich loess areas and broad valleys of the major rivers like the Rhine and the Meuse, although the label 'pine woodland' does require some qualification (see § 6.3.3). The surface of Flevoland for the first 4000 years of the Holocene was made up of Younger Coversands. These contained little loam, so water and nutrients would quickly leach out of a dry coversand soil, becoming inaccessible to vegetation. By the start of the Atlantic (7000 cal. BC), pine had dominated the vegetation on the dry coversands for over a thousand years. At the start of the Early Atlantic the coversands were fairly dry and acidic and had lost a large proportion of their nutrients. This had implications for the vegetation. In the course of the Boreal more and more cold-intolerant plant species, including many deciduous trees and shrubs, reached northwest Europe, after surviving in refugia in southern Europe during the previous ice age. Temperature is not however the only factor determining where plants establish themselves. Soil conditions, the hydrology, the availability of nutrients and of course the vegetation already present are also key factors. It therefore comes as no surprise that mixed oak and lime woodland did not develop in a landscape such as this. Lime trees need moist to dry soil rich in calcium. Such conditions did not exist in Flevoland in the Early Atlantic, although the vegetation did however change in the course of the period. The open pine woodlands slowly made way for a landscape in which open woodland alternated with vegetation featuring heather, hazel, oak, birch with only the occasional pine (fig. 6.15). Depending on local soil conditions, there would have been either more heather or more oak, or alternatively pine would still dominate. This variation was probably driven by differentiation in hydrological processes in the coversand subsurface. While pine continued to dominate in the higher and dryer areas in the east of Oostelijk Flevoland until well into the Early Atlantic, the vegetation in the low-lying central and western areas transformed into open woodland featuring oak and hazel (fig. 6.16). One explanation for these differences probably lies in the rising sea level, which hampered the drainage of excess water via the regional rivers in the central and western part of Flevoland. This probably also led to changes in groundwater flows and the hydrology of the coversand subsurface. Minerals that previously lay inaccessible, deep in the subsurface, may have been transported to the surface and therefore became available for the vegetation. The differentiation in the vegetation increased further in the second half of the Early Atlantic (fig. 6.17). Groundwater probably played a key role in this, although it had not yet reached the surface.

557 Cf. Janssen 1974; Van Geel *et al.* 1981.

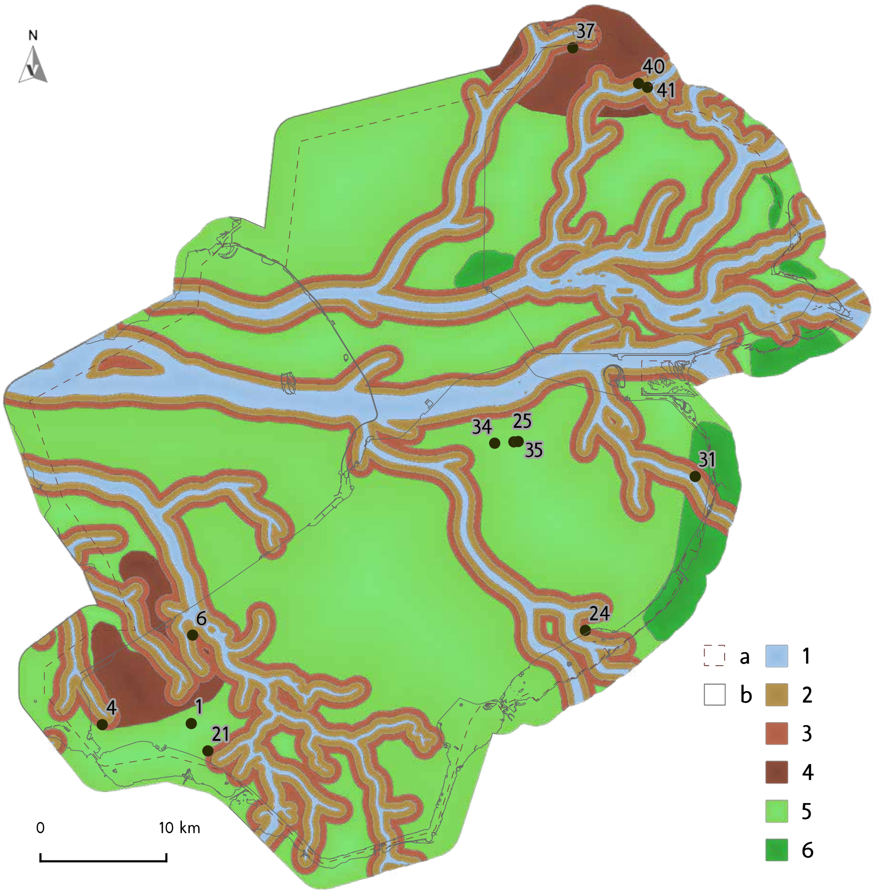


Figure 6.17: Reconstruction of the vegetation of Flevoland in the Early Atlantic based on palaeoecological information and after the palaeogeographical map of 9000 BC of Vos & De Vries (2018). Legend: a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers; 2: marshes and swamps along the rivers with reed and alder; 3: fens in the river valleys with reed and alder carr; 4: bog like vegetation in the river valley of the Eem and in the north; 5: open woodland on the dry soils with deciduous species (oak, birch, elm and possibly lime), species of the grass family and species of the heath family; 6: open woodland on some of the dry soils with pine, birch, hazel, oak, elm (and lime), grasses, species of the heath family.

6.3.5 Middle and Late Atlantic : 6000 – 3700 cal. BC (Late Mesolithic and Early Neolithic)

Geology, climate and hydrology

We have no detailed information about the climate in the Middle and Late Atlantic. Generally speaking, it would have been an Atlantic climate, with relatively mild winters and cool summers, due to the proximity of the sea. With prevailing winds from the west, there would have been quite a lot of rainfall.

During this period, the hitherto relatively uniform coversand landscape of Flevoland began to show more differentiation. The drivers behind this development were the rising water level and land subsidence, two processes connected with the last ice age. The rising sea level was the result of the further melting of land ice in northern Europe and other regions. This caused the subsurface to rise in these areas, and led to land subsidence elsewhere, in Flevoland for instance, in a process known as glacio-isostasy (see also chapter 3). Although, in an absolute sense, the sea level rose less rapidly in this period because there was less remaining land ice, as a consequence of land subsidence it actually rose by several decimetres a century. Around 3700 cal. BC the water level in Flevoland had risen to approximately five metres below NAP.[558] Large areas of Flevoland's Pleistocene coversands were covered with water, clay and/or peat (see fig. 6.1b/c, fig. 6.2).

The river valleys and low-lying parts of the coversand area in the west were the first to be exposed to the effects of the rising water. Towards the end of the Atlantic (c. 3700 cal. BC), only the river dunes of Oostelijk Flevoland

558 Makaske *et al.* 2002b, 2003; Van de Plassche *et al.* 2005; Roeleveld & Gotjé 1993.

Figure 6.18: Start of terrestrialization at a flood basin of the Kasari River (Estonia) just before it ends up in the Matsalu Bay of the Baltic Sea (photo: BIAX *Consult*/L.I. Kooistra).

and the Noordoostpolder, the outcrops of glacial till in the Noordoostpolder and the higher coversand areas in the east of Zuidelijk and Oostelijk Flevoland and the northeastern Noordoostpolder were still visible on the surface, as 'relics' of the Pleistocene landscape.

The first beach barriers developed in the western Netherlands at the end of the Late Atlantic (between 4200 and 3700 cal. BC). Over the subsequent millennia, they would grow into effective barriers against the sea, although during the Middle and Late Atlantic Flevoland still maintained an open connection to the sea via Noord-Holland (fig. 6.1b/c). The North Sea is a shallow sea, especially in the flooded areas of western Netherlands. Given that the sea level in the Atlantic was lower than it is today, the North Sea would also have been shallower. Furthermore, it is assumed that the sea bed was less steep. Like today, the difference between ebb and flood along the coast of Noord-Holland would have been smaller than along the rest of the western and northern coast of the Netherlands.[559] These factors give reason to assume that though the sea level was rising, the influence of the tides was not strong in Flevoland, although this would have had some influence on the hydrology of the region, resulting in a much more constant marine water pressure than would have been the case had the amplitude between ebb and flood been greater.

Water pressure was also exerted by fresh water from the landward side. The coversand areas of the central Netherlands drained water to the sea via regional rivers: the Eem, Hunnepe and Overijssel Vecht. Exactly how much fresh water flowed into the sea each year is not clear. In addition to the physical properties of the subsurface, the amount of fresh water would also have depended on factors like the annual rainfall and – very importantly – the types of vegetation in the region.[560] Given the source area for each of these regional rivers in Flevoland (the Drenthe plateau, Overijssel, Gelderland and the Utrechtse Heuvelrug ice-pushed ridge), it is, however, likely that substantial amounts of fresh water were discharged.[561] It is therefore reasonable to assume that large volumes of marine and freshwater collided, perhaps even forming layers, whereby the heavier marine water would have sunk beneath the fresh water.

The fact remains that many researchers have struggled to explain the presence of fine-grained sand and clay deposits of marine origin, which were largely deposited under water, while there are also indicators of fresh water present.[562] Not only the clay itself, but also diatoms and foraminifera in the clay provide indisputable evidence of its marine origin.[563] However, what was originally

559 Vos 2015.

560 The hydrology of a landscape can be modelled on the basis of knowledge of the palaeovegetation and the reconstructed groundwater curve for Flevoland, using simulation models. However, no such studies have been performed.

561 Much less, however, than in the Zuid-Holland coversand area, where two major European rivers – the Rhine and Meuse – enter the sea. It is not therefore surprising that the marine influence here did not extend further to the east, despite the greater tidal amplitude.

562 This is known, in the current geological typology of the Netherlands, as the 'Wormer Member' (*laagpakket van Wormer*). For arguments supporting deposition of clay under water, see Ente *et al.* 1986, 52, 54; Menke *et al.* 1998, 38.

563 Ente *et al.* 1986; Menke *et al.* 1998.

Figure 6.19: Examples of accumulation of washed up material by a. wind and weak currents (Texel, the Netherlands), and b. by wind, ice and strong currents (Pripyat River, Belarus), (photo: BIAX *Consult*/L.I. Kooistra).

marine clay also contains shells of freshwater mussels (Unionidae), which in the past led geologists to refer to the clay as 'Unioclay'. Plant remains found in the clay are also typical of freshwater marshes. Plant remains from brackish or salt water, and plant remains that represent saline marshes have been found only occasionally, if at all, dating to this period in Flevoland. This is in contrast with the coastal region of Zuid-Holland, for example, where a period of saline marshes has clearly been identified.[564] It was commonly assumed by geologists that in Flevoland, as in the western coastal area, the clay had been deposited in an intertidal zone, which fairly rapidly evolved into a freshwater tidal zone.[565] However, the botanical data discussed in the following section show that there was no tidal influence whatsoever.

The inundation of the Pleistocene landscape followed a more or less fixed pattern in the Middle and Late Atlantic. Initially, localised water levels existed in the coversand region, a result of differences in relief and the diversity in stratification of the subsurface. As the sea level rose, the localised water levels became part of a groundwater regime linked to sea-level rise. Where the fresh water subsequently reached the level of the Pleistocene surface as drainage water stagnated, peat generally began to accumulate. The ongoing rise in the sea level and stagnation in the drainage of fresh water lead to inundation of the peat, and the covering of the peat with a layer of marine clay deposited under water.[566] When, towards the end of the Atlantic (between 4200 and 3700 cal. BC), the process of clay sedimentation in Flevoland slowed down, peat could again begin to form and accumulate. This occurred in part on top of the clay deposits, on top of the low-lying coversands further inland and on the higher coversands where no clay had been deposited. The latter were not affected by the rising water until the end of the Late Atlantic. On these higher grounds, mires formed directly on the coversand. In some places, however, shallow lakes with a clay bed formed, which then became overgrown with vegetation from their shores. Reed and marsh fern played a particularly important role in this process. Such plant species grow into the water from the bank forming floating mats that provided a place for other mire vegetation to establish itself. Over time a shallow area of water can become covered by a floating layer, or mat, of peat formed in this way (fig. 6.18). Mire vegetation then grows on top of the peat, whilst water from the original lake is still underneath. A process of continuous accumulation results in an increasingly thicker and heavier layer of peat, the base of which will sink, due to its weight, and eventually touch the original lake bed.[567]

As far as is known, the first clay deposits in Flevoland occurred in the Eem estuary between 5300 and 5000 cal. BC.[568] The first clay was deposited in channels of the

564 E.g. Kubiak-Martens 2006.

565 Ente *et al.* 1986, 49; Menke *et al.* 1998, 38; Vos *et al.* 2020 (see also fig. 6.1b/c).

566 The Wormer Member (*laagpakket van Wormer*).

567 Dating the base of peat formed in this way will give a start date for accumulation, but the level at which it is found is not the level at which it is formed. Such bodies of peat are not therefore suitable for reconstructing the rise in the water level or for determining the moment at which the landscape was inundated. Only peat that is known to have accumulated on coversand and that was not subject to sinking or subsidence – where it can be shown that peat plants were rooted in the coversand, for example – is suitable for this type of analysis.

568 Derived from Van der Linden 2010. Menke *et al.* (1998, 40) published a date for sedge-reed peat with humic clay that falls between 4538 and 4337 cal. BC (5585±60 BP; GrN 6716).

Hunnepe and Overijssel Vecht shortly afterwards.[569] In the western part of Flevoland, the clay transported via the river valleys spread over the low-lying coversand. Over 1000 years later, between 4300 and 4000 cal. BC, the process of clay sedimentation and the inland expanding water surface temporarily ceased. Some of the clay dried out during this period, and marshy areas developed with channels, levees and flood basins. The fine-grained texture of the clay on the levees was the same as that in the flood basins behind them, suggesting that the clay was deposited in calm waters. The clay on the levees was firm, however, while the layer deposited under water in the flood basins was of a softer consistency.[570] At the boundary between water and land bands of detritus formed consisting of organic remains (generally of plant origin) that had been washed up by water.[571] Such accumulations of washed up material can be caused by the wind and weak currents (fig. 6.19a-b). These bands of detritus are generally richer in nutrients than the surrounding environment, enabling a lush vegetation to develop on it. Over the course of time, as more and more organic material accumulates, these bands of detritus can even develop into slight elevations in the landscape.

The marshes probably developed on the deposit of clay in western Flevoland as sea-level rise slowed. In the coastal region of the western Netherlands this resulted in the formation of more solid complexes of sandy beach barriers. The deposit of clay and the nutrient-rich water allowed a rapidly growing marsh vegetation to develop in the low-lying part of western Flevoland. The dead plant remains formed eutrophic peat, the accumulation of which kept pace over several centuries with the rising water level.

Vegetation development in the Middle and Late Atlantic

For the previous periods vegetation development has been discussed per location. The developments at the different locations are very comparable, so to avoid repetition, this paragraph will suffice with a single overview of the types of vegetation that occurred in the Middle and Late Atlantic. At locations where the Pleistocene coversand lay more than five metres below NAP, the changing conditions meant that the climax vegetation that developed there was forced back. The types of vegetation described below not only succeeded each other, but also occurred simultaneously, depending on the depth of the Pleistocene surface. Four maps show the distribution of the reconstructed vegetation types in Flevoland over time (fig. 6.20).

There is evidence for heathland on the dry, relatively nutrient-poor coversands. Depending on the availability of nutrients in the subsurface and the hydrology, the heathlands would have been overgrown with trees. Birch and oak were scattered across the nutrient-poor, dry areas. Pine also occurred locally at the start of the Middle Atlantic, though it disappeared from the vegetation during the course of the Atlantic. The widely encountered remains of hazel probably came initially from bushes that grew in places with nutrient-rich (river) deposits in the shallow subsurface. At the start of the Middle Atlantic these locations were more likely to be in river and stream valleys, low-lying areas and on the flanks of coversand ridges rather than on the tops of the higher coversand ridges. In the more nutrient-rich areas with lots of hazel, the density of deciduous trees would also have been higher, Oak and birch being the most common. The proportion of elm and lime increased in the course of the Middle and Late Atlantic. Of all these deciduous trees, lime is the only one that creates and prefers dense, shady woodland. The increase in lime during the Atlantic suggests the soil was richer in nutrients and less acidic, and that the hydrology of the subsurface improved. A rising water level no doubt made the climate in Flevoland more attractive for lime, which requires a water level that is not too deep, but equally not too close to the surface. As long as the groundwater remained within this particular bandwidth it would have led to improved hydrological conditions in the coversand. The groundwater probably transported minerals from the deeper substrate. An increase in the number of deciduous trees thus creating open, or even dense, woodland, would, however, also have improved the soil conditions. A different, thicker layer of leaf litter would have developed in deciduous woodland, partly because in the temperate climate zone of Europe deciduous trees shed their leaves in winter. The litter layer would have attracted a greater variety of mesofauna and microfauna. The decomposing leaves would have contributed to an increase in the humus content of the soil which meant that rainwater could be retained in the soil for longer and minerals would have leached out less quickly.[572]

Depending on the hydrology, the level of nutrients, the acidity and the amount of incompletely decomposed

569 Date 6200 to 6250 ^{14}C-years BP (Ente *et al.* 1986, 123-126; Gotjé 1993, 109; Wiggers 1955). Improved calibration programmes have put back the start of clay formation to over 500 years earlier than these authors assumed.

570 Ente *et al.* 1986, 126; Huisman *et al.* 2009; Dresscher & Raemaekers 2010.

571 Detritus is generally regarded as an accumulation of coarse organic material, including dead plants and animals that lived in the water (see Ente *et al.* 1986, 55 and others). It is deposited in a watery environment. The nature of the material in the bands complies with this definition: coarse organic material deposited at the water's edge.

572 Kooistra & Pulleman 2010.

organic matter, the marshes in the river and stream valleys of the Pleistocene area took the form of either swamps or carrs, reed, sedge marshes or fens, which would eventually develop into bogs.

The composition of the deciduous woodland on the coversand changed depending on how close the water table came to the surface. Oak was probably able to survive the longest. This is indicated by the many, fairly intact oak trunks and root systems found at location 10 (Hoge Vaart-A27) in Zuidelijk Flevoland (fig. 6.2, table 6.1). Such remains are only preserved if they end up in anaerobic conditions fairly soon after they die, *i.e.* under water or embedded in peat. Around 4900 cal. BC the water table at location 10 was so high that the soil of the coversand ridge began to develop hydromorphic characteristics. Palynological data, dendrochronological measurements and two ^{14}C-dates for oak roots suggest that the last oaks disappeared from the landscape soon after 4600 cal. BC.[573] The same development has been observed at location 25 (Swifterbant-N23) in Oostelijk Flevoland (fig. 6.2, table 6.1). Here, several dozen oak trunks and root systems have been found on the Pleistocene coversand. One of the trunks has been dendrochronologically dated to after 4799 cal. BC.[574] Interestingly, the wood at locations 10 and 25, which were found at more or less the same depth – 6.00 and 6.70 metres below NAP respectively – gave similar dates.

Tree ring patterns indicate the conditions in which trees grew. If broad rings form, the conditions are good; narrow rings suggest poor growing conditions. The tree ring patterns of the oaks at Dronten-N23 (location 25) show an alternation between very narrow and slightly wider rings (fig. 6.21). No increase in the number of narrow rings has been observed during the lifetime of the trees, which might mean that the water level was rising. The periods with narrow rings occurred when the trees were still young. There seems to be a pattern of several poor years followed by a period of slightly better growing conditions. Since there was no bark or sapwood, it is not known what the growing conditions were like in the final years of the trees' growth. Almost a hundred growth rings have been counted on two tree trunks. They were small trees, with estimated trunk diameters of 20 and 50 centimetres. Despite the slightly broader growth rings, these were therefore trees that experienced at least a hundred years of poor growing conditions, undoubtedly due in part to the high water level.

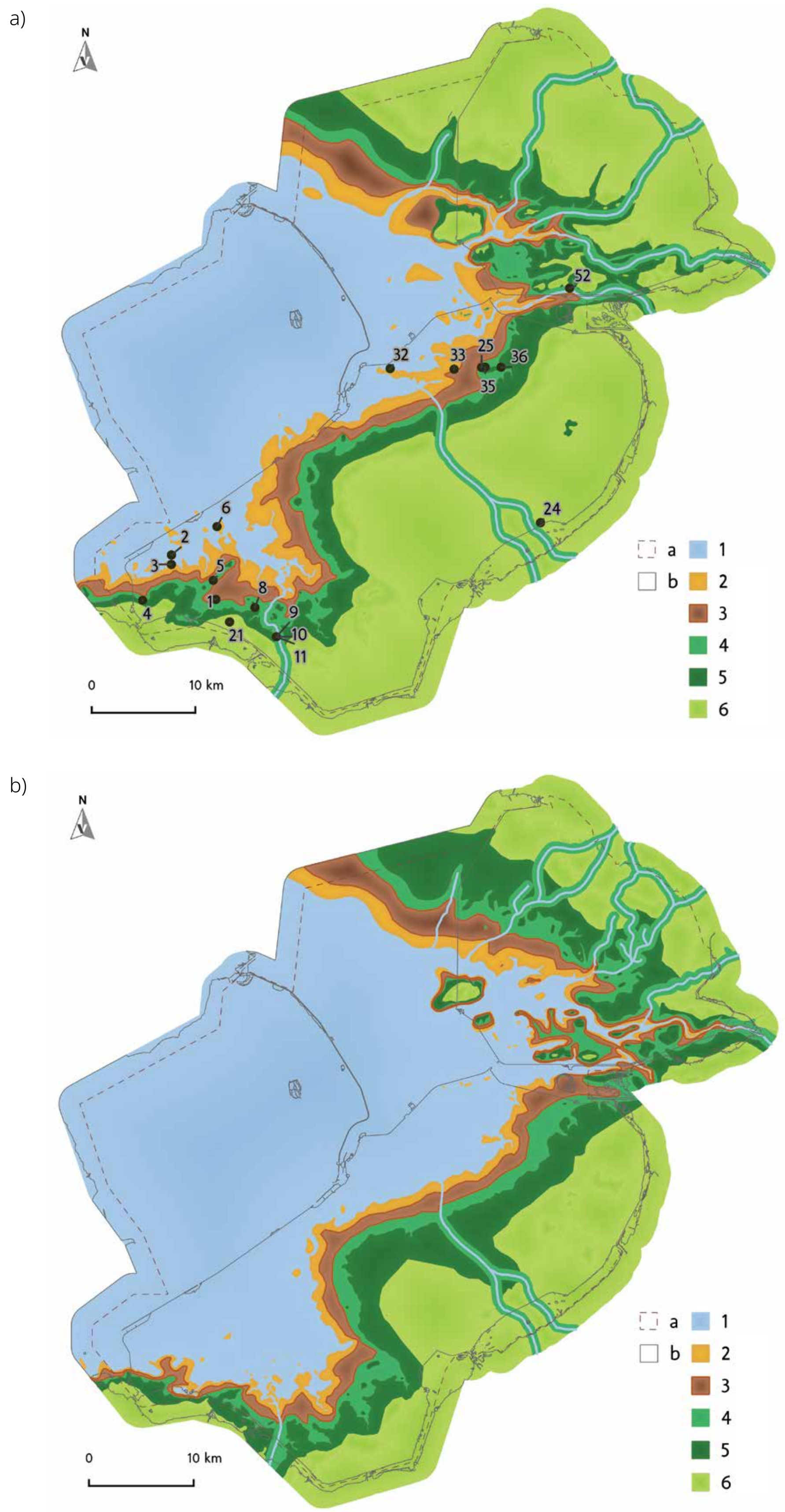
In many places the deciduous woodland transformed into carr with alder and birch as well as reed and sedge. Where peat accumulation did not keep pace with the rise in the water level, alder carr transformed into sedge reed fens where bulrush, bur-reed, marsh fern, bogbean and yellow iris grew. In places where the water was more than a metre deep, the fen vegetation declined and eventually disappeared entirely. The land disappeared under open water with no vegetation. Whether this water was fresh, saline or layered is not known.

The first phase of clay sedimentation appears to have occurred in open water in many places, given the virtual absence of plant remains. It was not until sea-level rise slowed at the end of the Late Atlantic that marsh flora re-established themselves. The ongoing sedimentation of clay had made the water shallow, and channels with levees and flood basins had started to develop. This means that the water was largely fresh by this time, leading to a succession of different types of vegetation. However, the continuing rise in the water level halted this process in a number of places, allowing the same type of vegetation to grow there for a much longer time. In other places, where other factors prevented plant growth from keeping pace with the rising water (for example, places with less nutrient-rich water), the succession either reversed, or open water took the place of vegetation. In some places, the marsh vegetation developed to a climax, which in these succession series meant a development from reed marshes to reed fens, to carrs, sedge fens and, eventually, raised bogs. Over the long term, factors such as rising water and the nutrient content of the soil, lead to the

573 Peeters *et al.* 2001, 37; Spek *et al.* 2001a, 86 & 137. Dates of oak roots: one between 4909 and 4730 cal. BC (5940±46 BP, UtC-5062) and one between 4785 and 4693 cal. BC (5856±46 BP, UtC-5061).

574 Kooistra 2012b, 373-374 (RING-report 2011068: RING Dendrocode: DRT00050).

Figure 6.20a-d (following spread): Reconstruction of the vegetation of Flevoland in the Middle and Late Atlantic in 5500 cal. BC (a), 5000 cal. BC (b), 4500 cal. BC (c) and 4000 cal. BC (d) based on palaeoecological information and after the palaeogeographical map of 3850 BC of Vos & De Vries (2018). Legend 6.20a-c: a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers and open water; 2: reed fens, alder carrs, birch carrs; 3: bog like vegetation; 4: deciduous woodland with oak and alder; 5: deciduous woodland on moisture soils in the coversand area with oak, lime and elm; 6: open woodland on the dry soils in the coversand area with deciduous species (oak, birch, elm and possibly lime), species of the grass family and species of the heath family. Legend 6.20d: a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers and open water; 2: reed marshes and swamps on clay deposits; 3: reed fens, alder carrs, birch carrs; 4: bog like vegetation; 5: deciduous woodland with oak and alder; 6: deciduous woodland on moisture soils in the coversand area with oak, lime and elm; 7: open woodland on the dry soils in the coversand area with deciduous species (oak, birch, elm and possibly lime), species of the grass family and species of the heath family.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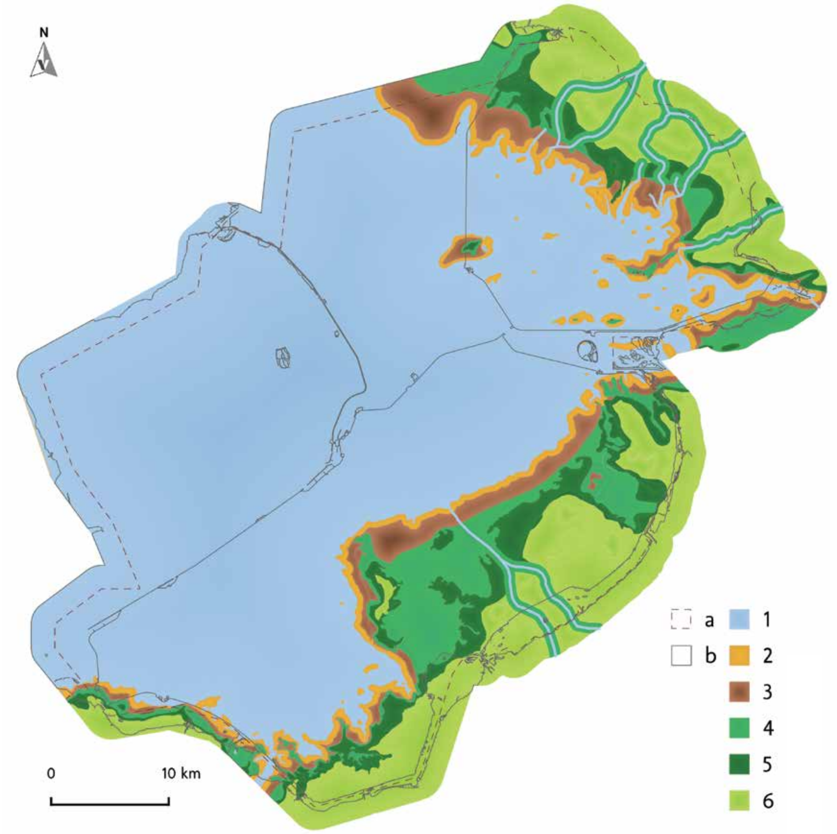
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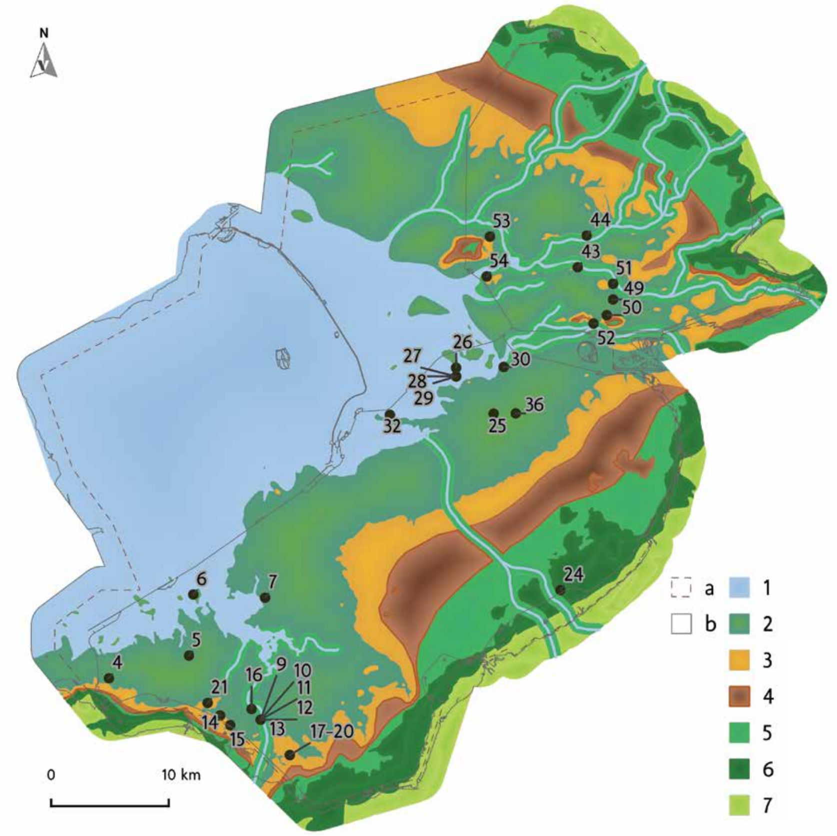
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Figure 6.21: a) Oak trunk in situ at Dronten-N23 (location 25), b) the growth ring pattern of one of the oaks from Dronten-N23 (location 25), (photo: BIAX *Consult*/L.I. Kooistra).

Figure 6.22: a) Impression of vegetation with reed and saw-sedge (Nieuwkoopse Plassen, the Netherlands), b) flowering bogbean (near the Nieuwkoopse Plassen, the Netherlands) (photo: J.A. de Raad).

development of a mosaic of different types of vegetation and open water.

Reed roots have been found in the clay deposits at a number of locations, indicating that reed was an important component of the Flevoland marshes after the flooding of the Pleistocene landscape in the Middle and Late Atlantic. This is remarkable, given the specific requirements that need to be met for reed to become established. The seeds can namely only germinate in water-saturated locations on land or on levees. The seedlings can neither withstand flooding, nor survive drought.[575] The water level must therefore be constant during germination and initial establishment – the growing season, in other words. Once reed has established itself, it can withstand a certain amount of fluctuation in the water level and a degree of salinity in the water. The reed colonisation of the clay area of Flevoland during the period in question suggests that there can have been little or no tidal movement occurring at that time.

The analyses present a picture of relatively nutrient-rich marshes in which reed, saw-sedge (fig. 6.22a), lesser bulrush, common bulrush, grey club-rush, common club-rush and yellow iris dominated. Further from the open, nutrient-rich water, and beyond the reach of clay sedimentation, these marshes developed into wet fens. The spectrum of fen vegetation remained to some extent the same, but also including other species associated with slightly acidic environments, such as marsh fern and bogbean (fig. 6.22b). Where terrestrialization continued, the vegetation transformed to alder carr, and then to birch carr and raised bog. Such successions

575 Weeda *et al.* 1994, 192.

in vegetation development mainly occurred far from open waters.

Trees and shrubs grew on the driest parts of the levees and in the clay-rich flood basins at the end of the Late Atlantic. Alder and willow grew in the wettest places. This again suggests there were no tidal movements since, whilst alder is adapted to wet environments, it cannot withstand changeable water levels during the growing season. Oak, hazel, ash and elder grew in higher spots.[576] As peat continued to accumulate, space became available for birch.

6.3.6 Subboreal: c. 3700 – 1100 cal. BC (Middle Neolithic – Late Bronze Age)

Geology, climate and hydrology

The sea level and the groundwater level in Flevoland rose from approximately five metres below NAP to between one and two metres below NAP during the Subboreal. Halfway through the Subboreal, around 2300 cal. BC, the water level had risen to slightly above three metres below NAP.[577] Virtually the entire Pleistocene landscape was covered with either peat, clay or water (fig. 6.1c-e). Detritus gyttja was deposited in water over two metres deep.

Dry coversands occurred on the surface only in the Noordoostpolder, in the west near Urk and in the east near Voorst, and in the far east of Zuidelijk Flevoland. There were levees along the Overijssel Vecht that were dry enough to allow habitation, such as evidenced by human habitation remains at Emmeloord J97 (fig. 6.2, table 6.1, no. 44). There may also have been dry levees along the Hunnepe, though no evidence of this has yet been found. Parts of the Eem valley became overgrown with peat, and lakes formed in the former Eem estuary.

Geological developments in the Subboreal were dominated by the closing off of the coastline in the western Netherlands and the formation of peat. At the end of the Late Atlantic, as soon as sea-level rise began to slow, wave action perpendicular to the western Netherlands coastline deposited sand, which resulted in the formation of sandy tidal flats .[578] The sand that lay above the water began to drift, creating systems of beach barriers and dunes that in combination eventually formed a single barrier to the sea. Behind them, peat formation started on a large scale. Initially, there were many openings in the beach barriers, particularly at the mouths of the major rivers, the Rhine, Meuse and Scheldt.

Although the Noord-Holland coast closed off entirely during the course of the Subboreal, in northern Noord-Holland a connection between the sea and the hinterland extending as far as Flevoland. Known as the Bergen Inlet, this connection continued to exist for some considerable time (fig. 6.1e). At the start of the Subboreal, the formation of the Bergen Inlet and the associated channel system changed the course of the river Overijssel Vecht in the Noordoostpolder. The Overijssel Vecht had originally flowed to the south of the outcrop of glacial till at Tollebeek and Urk. A channel of the Bergen Inlet penetrated into the Noordoostpolder to the north of these outcrops and joined the Overijssel Vecht to the north of the outcrop of glacial till at Schokland, after which the Overijssel Vecht no longer followed its southern course. Somewhere to the west of Flevoland a branch of the river Hunnepe presumably joined the Overijssel Vecht or the Bergen Inlet channel system, though less is known about this. In southern Flevoland peat rivers and lakes drained into the sea via the Oer-IJ estuary. Halfway through the Subboreal (around 2000 cal. BC) saline and brackish water penetrated Flevoland via channels and rivers. Sea water penetrated Zuidelijk Flevoland via the Oer-IJ estuary. The Noordoostpolder and Oostelijk Flevoland became subject to marine influences that spread via the Bergen Inlet, the Overijssel Vecht and the Hunnepe.[579]

Paradoxically, as the sea inlets in Noord-Holland narrowed, the start of large-scale peat accumulation in the Subboreal probably also allowed saline and brackish water to penetrate into Flevoland. Peat accumulation not only reduced the storage capacity for sea water,[580] but also led to stagnation in the drainage of fresh water. Research has shown that raised bogs in eastern Poland store large quantities of water. Forty million cubic metres of raised bog can hold 34 million cubic metres of water. Only 5% of this water circulates; the other 95% remains in the bog as long as it does not oxidise or erode.[581] If an area of peat is stable, water discharge will remain more or less constant. In the Subboreal, however, peat developed on a massive scale in large areas of the Netherlands (fig. 6.1c-e). This included the formation of raised bog, which expanded not only in area, but also in thickness. Peat also accumulated on a large scale in the source regions of the Eem (to the south of Zuidelijk Flevoland), the Hunnepe (to the east of Flevoland) and the Overijssel Vecht (to the east and northeast of Flevoland). While the raised bog was expanding in this way, each year it would have retained

576 Incl. De Jong 1966; Kooistra 2014; Raemaekers *et al.* 2010.

577 Based on Makaske *et al.* 2002a; Van de Plassche *et al.* 2005. As regards the water table in 2300 cal. BC, see Van Smeerdijk 1989, 478. In southern Flevoland, at location 22 (see figure 6.2; table 6.1) peat that developed at 2.72 m below NAP has been dated to between 2561 and 2141 cal. BC (3870±70 BP, GrN-13035).

578 Though most of the land ice had melted, subsidence was still occurring as a result of glacio-isostasy (see chapter 3).

579 Incl. Menke & Lenselink 1991.

580 For more information on the concept of 'accommodation space', see Coe 2003, 58-61.

581 Tobolski 2000, 28-30.

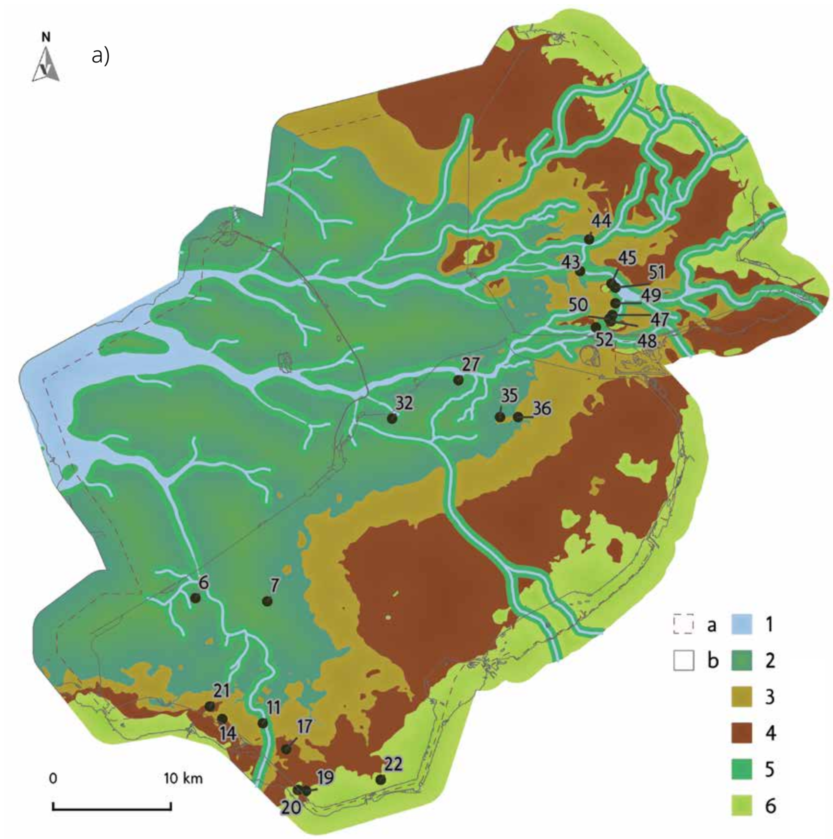


Figure 6.23a-c: Reconstruction of the vegetation of Flevoland in the Subboreal in 3500 cal. BC (a), 2500 cal. BC (b) and 1500 cal. BC (c) based on palaeoecological information and after the palaeogeographical maps of resp. 3850 cal. BC, 2750 cal. BC and 1500 cal. BC of Vos & De Vries (2018).

Legend 6.23a: topography; b: outline of research area; dot: locations of palaeoecological information (table 6.1); 1: rivers and open water; 2: reed marshes and swamps on clay deposits; 3 reed fens, alder carrs, birch carrs; 4: bog like vegetation; 5: deciduous woodland with oak and alder; 6: open woodland on the dry soils in the coversand area with deciduous species (oak, birch, elm and possibly lime), species of the grass family and species of the heath family. Legend 6.23b-c: a: topography ; b: outline of research area; dot: locations ofpalaeoecological information (table 6.1); 1: rivers and open water; 2: reed fens, alder carrs, birch carrs; 3: bog like vegetation; 4: deciduous woodland with oak and alder; 5: open woodland on the dry soils in the coversand area with deciduous species (oak, birch, elm and possibly lime), species of the grass family and species of the heath family.

more water than it drained. It is not impossible, therefore, that this might have caused the counter-pressure of the fresh water in the regional river systems to decrease to such an extent that marine water was able to penetrate further inland via tidal channels and rivers.

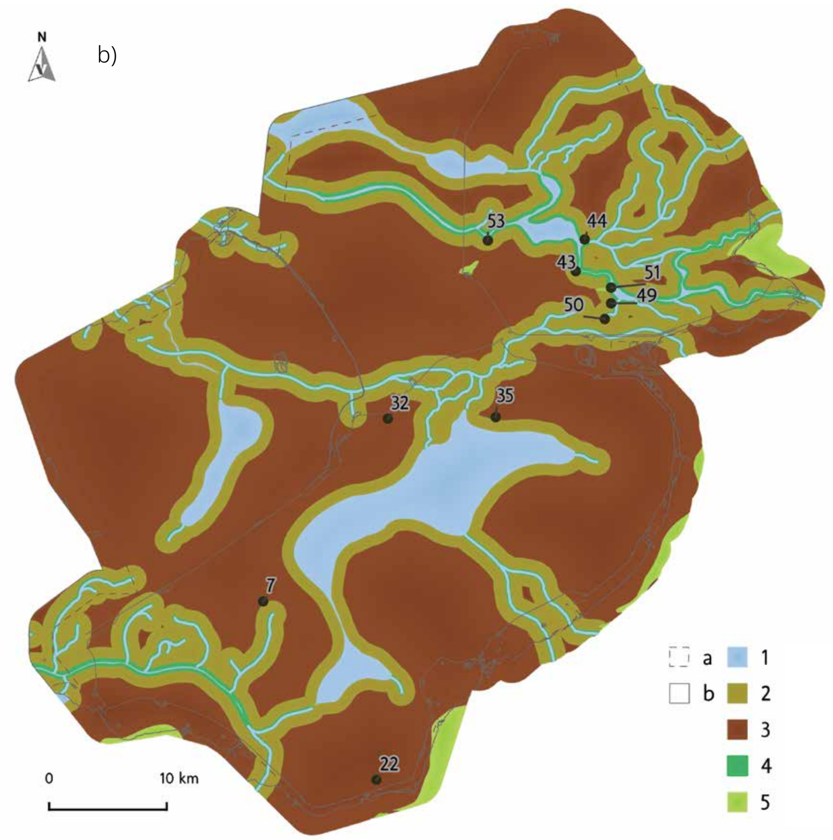
In the second half of the Subboreal more saline to brackish water reached Flevoland than in the Atlantic, as suggested by the presence of foraminifera, dinoflagellates and molluscs from brackish waters in clay layers deposited in this period. Bivalve molluscs have been found, particularly *Cerastoderma glaucum*. This mollusc used to be known as *Cardium edule*. The clay in which it was found has also been referred to as *Cardium* clay in the past.[582] The presence of doublets of this mollusc species means that these invertebrates lived at the location. Large shells suggest a mainly marine environment, small shells suggest a more brackish one. Doublets of *Cerastoderma glaucum* have been ^{14}C dated in order to determine the age of the clay.[583] Doublets found in Zuidelijk Flevoland proved to be 4220±90 and 3975±35 ^{14}C-years BP old.[584] In Oostelijk Flevoland they dated to 3995±40 BP,[585] and in the

582 In the literature this clay deposit is regarded as part of the Wormer Member (*Laagpakket van Wormer*).

583 *Cerastoderma glaucum* is a bivalve species. Finding doublets in a clay deposit means that the creatures lived at the location. If only single shells or broken shells of the species are found in a sediment, the origin of the invertebrate is unclear. It may have lived in the clay at the location found, or, alternatively, it might have been transported in with the clay. In such a situation, the shell might come from an older sediment.

584 Menke *et al.* 1998, 40. The doublets in the clay deposit at Tureluurweg dated to 4220±90 BP (GrN-11498); those from Almere plot Az 122/123 dated to 4010±100 BP (GrN-18358); those on Wulpweg dated to 3975±35 BP (GrN-19513).

585 Ente *et al.* 1986, 57, in the Swifterbant region plot G42c (GrN-7082).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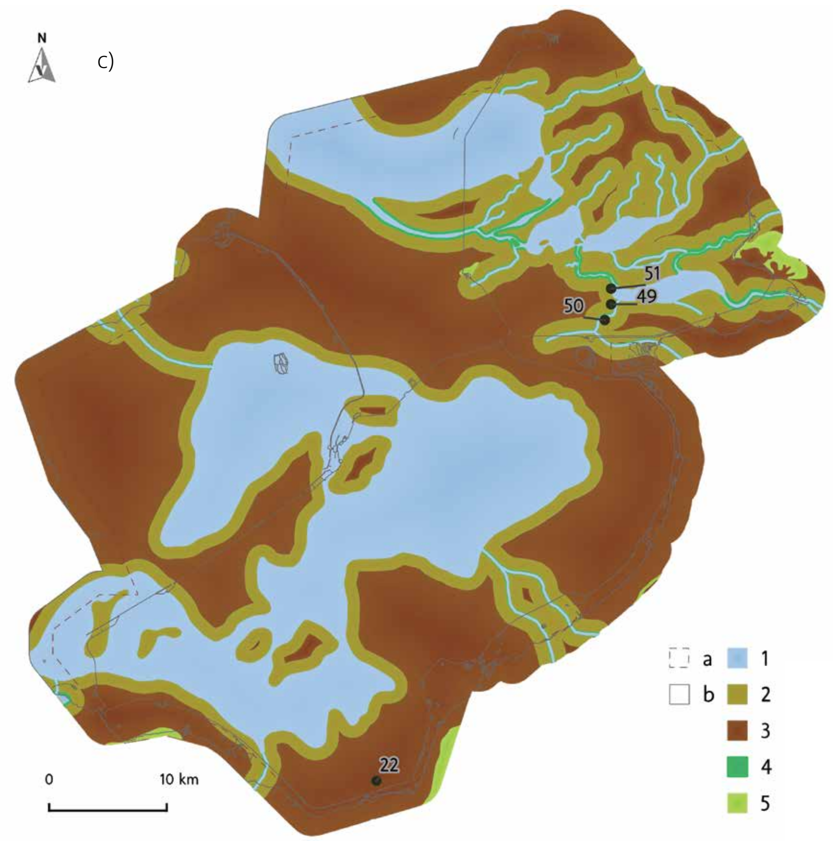
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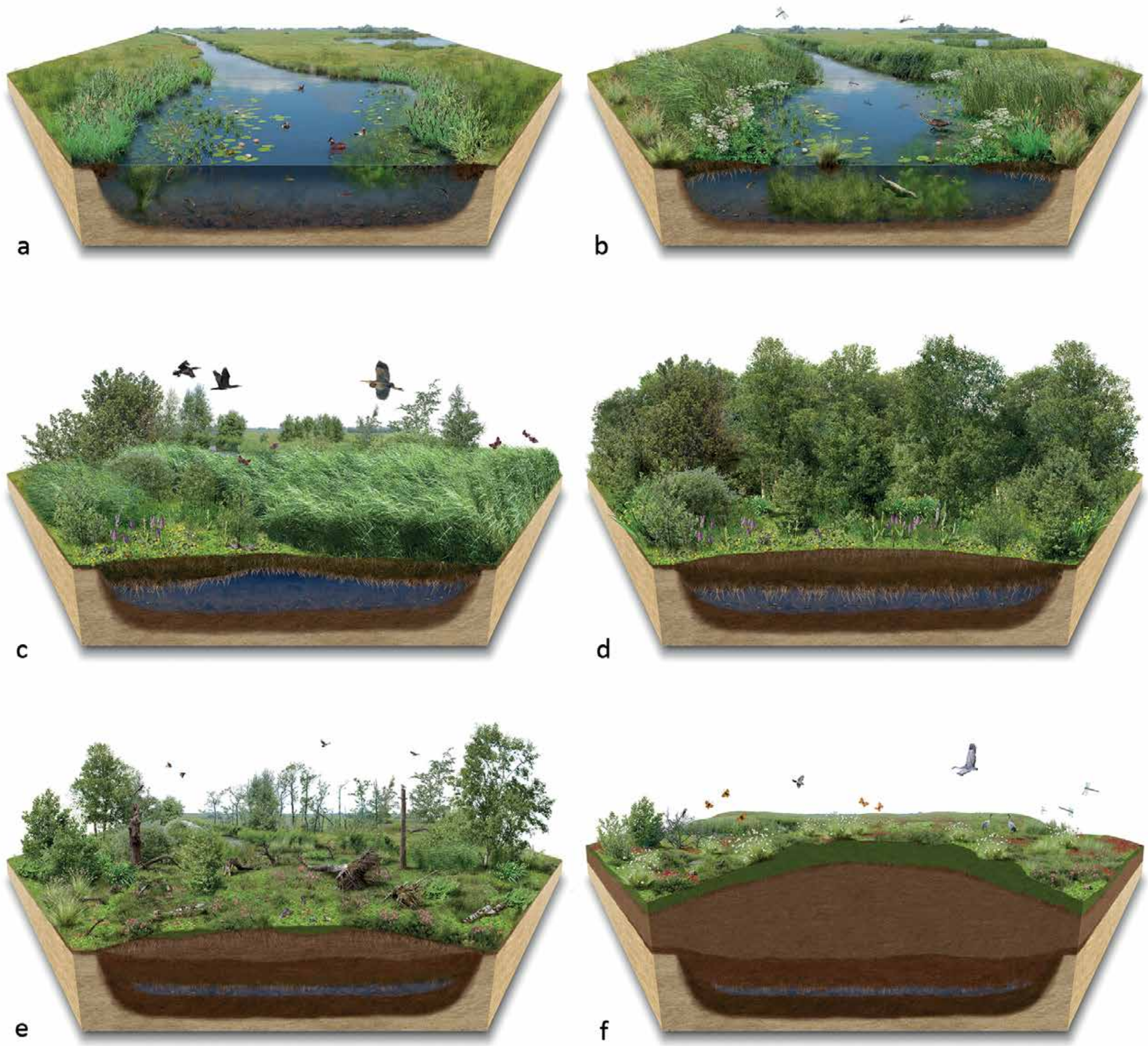


Figure 6.24a-f: The vegetation development from open water to peatbogs in the Natura2000 area Nieuwkoopse Plassen van Natuurmonumenten (the Netherlands), a) open water, b) development of floating vegetation on shores and development of detritus, c) floating reed fens and development of a detritus layer, d) alder carr, e) transition to raised bogs, f) raised bogs (drawing by Wim Dasselaar).

Noordoostpolder to 3920±60 BP.[586] However, given that aquatic organisms derive carbon not from the atmosphere but from water, we must consider the reservoir effect, which can mean that the age measurement turns out older than the actual age. The reservoir effect of carbon in marine environments for Dutch coastal waters is approximately 400 years, which must be deducted from the dates which are calibrated with atmospheric carbon.[587] The carbon in brackish water, however, comes partly from a marine environment and partly from river systems. The reservoir effect can differ markedly from one river system to another, and depends on the layers through which the river flows on its way to the sea. The difference can be as great as 1000 years.[588] From the ^{14}C datings of *Cerastoderma glaucum* can therefore only be deduced with any certainty that the molluscs lived in the Flevoland clay sometime after 3000 cal. BC.

586 Koopstra 1981, at Tollebeek II (GrN-10623).

587 Reimer & Reimer 2001.

588 Cf. Culleton 2006, Philippsen 2012; 2013.

Figure 6.25: Impression of a raised bog. Fochteloërveen (the Netherlands) (photo: BIAX *Consult*/L.I. Kooistra).

Dated peat from Zuidelijk Flevoland and the Noordoostpolder accumulated at the same time as the clay sedimentation took place. On Schokland, a date comes from a small layer of peat embedded in the '*Cardium* clay', which formed between 1876 and 1416 cal. BC.[589] In the east of Zuidelijk Flevoland, peat formation dates between 2550 and 1750 cal. BC coincide with the estimated age of the *Cardium* clay.[590] Together, these data suggest that clay deposition occurred between 2500 and 1500 cal. BC. The influx of brackish or saline water in this period caused localised erosion, as evidenced by the presence of detrital plant remains and spoiled coversand in the Noordoostpolder.[591] Given the limited impact of these saline and brackish water incursions on the vegetation in Flevoland, it would appear that these were probably isolated events, rather than a protracted period of prevailing saline and brackish conditions in the area.

Between 1500 and 1350 cal. BC the Bergen Inlet silted up and the marine influence in the Noordoostpolder and Oostelijk Flevoland finally came to an end.[592] In Zuidelijk Flevoland the connection with the Oer-IJ estuary continued to exist, but the sea water no longer penetrated here. The connection served mainly to drain fresh water from Flevoland and the Pleistocene area partially overgrown by peat that lay beyond (Utrechtse Heuvelrug ice-pushed ridge, eastern Gelderland, Overijssel and the Drenthe plateau) (fig. 6.1f).

589 Wiggers 1955, 64-65; 3315±90 BP (GrO-377).
590 Van Smeerdijk 1989, 488-490; 3870±70 BP (GrN-13035); 3780±60 BP (GrN-13034); 3570±60 BP (GrN-13033).
591 Wiggers 1955, 60-62.
592 Cf. Berendsen 2011, 293.

Vegetation development in the Subboreal

The landscape of Flevoland in the Subboreal can be described, on the basis of the palaeoecological analyses (fig. 6.2, table 6.1), as comprising extensive mires with many interspersed lakes, through which rivers flowed (fig. 6.23b-c). There were only a few areas in the east of Zuidelijk and Oostelijk Flevoland where (initially) more or less dry Pleistocene coversands lay at the surface. There was probably mixed deciduous woodland growing on these subsurface at first, although information is scarce. In the course of the Subboreal, however, this woodland made way for mire vegetation. In the Noordoostpolder, mixed deciduous woodland was found not only in the north and east, but also on the outcrops of glacial till at Voorst, Schokland, Tollebeek and Urk, and possibly also on a river dune to the north of the Hunnepe.[593] Softwood and hardwood riparian woodland would also have grown on the levees of the Overijssel Vecht, certainly into the Middle Bronze Age (1800-1100 cal. BC), as evidenced, among other things, by the wood used to make fish traps found in a small tributary of the Overijssel Vecht (see chapter 4).[594] Botanical information for the last 1000 years of the Subboreal is scarce, but as long as rivers flowed through the Flevoland mires, there would have been higher silt levees supporting riparian woodland. Depending on the height of the levees relative to the water, these would have been softwood woodlands comprising willow, alder and poplar, or hardwood woodlands with oak, ash and elm.

There is no doubt that there was only a small area of dry subsurface in what is now Flevoland, and that this area reduced in size even further during the Subboreal.

593 Gotjé 1993; Weijdema *et al.* 2011; Ten Anscher 2012.
594 Van der Heijden & Hamburg 2002; Van Rijn 2002.

The landscape was largely a patchwork of lakes and mires. No land formation occurred during the transition from the Late Neolithic to the Early Bronze Age (probably between circa 2400 and 1800 cal. BC), at a time when the lakes contained saline or brackish water. Logically also no land formation occurred in the large freshwater lakes, where wave action eroded the shoreline and the peat.[595] Although the edges of large lakes can be subject to erosion, new land can also form on the shoreline. On the leeward side of a lake this occurs when reed beds grows into the water; on the windward side organic material can accumulate to form bands of detritus. Although it would seem that the deep lakes in Flevoland continued to exist, possibly 'wandering' through the mires, it is likely that shallow freshwater lakes grew over after a time. This process would certainly have occurred in part along the shoreline, as floating reed vegetation grew into the water (fig. 6.18).

Over the last hundred years of the Subboreal, the silting up of the Bergen Inlet and the fact that brackish and saline water disappeared from the channels and rivers of Flevoland, meant that seawater no longer entered the region via the Oer-IJ estuary. A mosaic of different types of mires developed in Flevoland and the surrounding region. The type of mire depended to a large degree on the hydrology, *i.e.* the quantity and origin of water, as well as its nutrient content and acidity. The types of mires that occurred when and where is not clear, as by no means all the vegetation zones in the layers of peat examined have been ^{14}C dated, and in many places the peat has been lost due to (natural or artificial) drainage. However, it is known that a variety of mire types existed, as indicated by the various stages of land formation on the peat (fig. 6.24). There is, for example, evidence for various types of reed fens (with or without saw-sedge, species of the sedge family, marsh fern and bogbean), alder carr, birch carr, transition mires with heaths and species of the sedge family and raised bogs (fig. 6.25).

6.4 A new view of the landscape

6.4.1 Pine woodlands and heathlands in the Atlantic (7000 – 3700 cal. BC)

It was long assumed that vegetation developed according to a fixed pattern in the Holocene. During the Preboreal (between 9800 and 8200 cal. BC), woodland dominated by birch initially developed on the Pleistocene subsurface of the Netherlands. In the second half of the Preboreal the woodland was dominated by pine. Open pine woodlands with undergrowth consisting of fern species, stag's-horn clubmoss and heath defined the look of the landscape in the Boreal (between 8200 and 7000 cal. BC). However, more and more cold-intolerant deciduous trees from Southern and Central Europe became established in the pine woods at the end of the Boreal. In the Atlantic deciduous trees displaced the pines and a mixed oak deciduous woodland with elm and lime developed. Swamps dominated by alder grew in the river and brook valleys. Humans increasingly influenced the vegetation from the Subboreal (3700 to 1250 cal. BC) onwards, and were a factor in the disappearance of elm and lime from the deciduous woodland. During the course of this period the area of woodland decreased, to be replaced by meadows, pastures and heathland. Beech first established itself in Dutch woodlands in this period.[596]

This interpretation of the palynological data, in particular, was first called into question towards the end of the twentieth century.[597] It was argued that the proportion of hazel and oak in the pollen diagrams was too high for dense woodland. Hazel is a shrub which these days grows on the edges of woodland and in glades. Oak requires a lot of light and is not therefore likely to be found growing in dense woodland with lime trees. The explanation for these results was said to be that large herbivores such as aurochs, elk, red deer and horses prevented the development of woodland after the last ice age, and that in the Atlantic the Netherlands had a varied landscape consisting of open woodlands with pastures and meadows in between.

An examination of the pollen diagrams for Flevoland from the first half of the Holocene (from 9800 to circa 5000 cal. BC) shows that this alternative interpretation is only partially correct. It looks very much like there was no dense pine woodland in Flevoland in the Preboreal and Boreal. The clear evidence of heath vegetation, stag's-horn clubmoss and ferns suggests that the pine woods of Flevoland were much more open. The diagrams containing data from the Early Atlantic (7000 to 6000 cal. BC) mainly show large amounts of pollen from hazel, oak, birch and locally also pine. This pollen, combined with palynological material from the heath family and grass family, suggests that in this period the landscape consisted of open oak woodland with heath in the undergrowth or heathland with scattered trees such as oak, hazel, birch and pine. Since the water level lay relatively far beneath the surface in Flevoland at that time, it is likely that the soil conditions determined these types of vegetation. A lack of water and leaching of minerals probably produced the kind of nutrient-poor coversands that are still found in the Veluwe and Noord-Brabant today.

The open landscape was not created by large herbivores, but by a loss of nutrients from the soil. However, it is not impossible that large grazing animals inhabited this landscape, though they were not the primary reason for the vegetation structure. This can be

595 Raemaekers & Hogestijn 2008.

596 Cf. Janssen 1974; Van Gijssel & Van der Valk 2005, 61-62.

597 Vera 1997.

seen from the vegetation development that followed this phase of heath and open deciduous woodland. The rising water level improved the hydrology of the coversand, and the deciduous woodland expanded. This caused the formation of humus, which improved the soil quality. Eventually, dense oak woodland with lime developed, as described in the classic version of vegetation development in this region. If large herbivores had been the cause of the vegetation structure at the start of the Atlantic, the later development of dense woodland could not have occurred.

There is differential relief in the Pleistocene coversand of Flevoland. Roughly speaking, the coversand in the west is lower than that in the east. The transformation from open woodland with birch, pine, oak and hazel, with heath, to dense oak woodland with lime first began in the low-lying west. Over the centuries this vegwetation zone shifted eastward. Palynological analysis combined with ^{14}C dating has shown that successive vegetation types could occur simultaneously on a spatial scale. This implies that the general picture of vegetation succession on a regional or sub-regional scale does not have any chronological basis.

6.4.2 No salt marshes or tides in the Late Atlantic (5000 – 3700 cal. BC)

By around 5000 cal. BC the water level had risen to approximately eight metres below NAP. Seawater moving via Noord-Holland towards Flevoland met the fresh water draining from a large proportion of the Netherlands via the rivers Eem, Hunnepe and Overijssel Vecht. It is not known which source dominated. It is however clear that the clay deposited on the inundated coversand region had marine origins. It did not however contain large numbers of marine organisms, but nor did it, at first, contain plant remains from freshwater marshes. It is generally assumed that the clay was initially deposited under water.[598] To this day, no plant remains from halophyte species have been found in any botanical survey. This could be because no botanical surveys have been performed in order to identify locations that were along the edges of the rising water. However, several studies have been performed on the coversand landscape around the Eem in southern Flevoland, which was gradually becoming inundated. None has produced information that might suggest the presence of saline marshes. For now, therefore, it seems likely that the saline marsh zone did not reach as far as Flevoland. Under the influence of the rising water, predominantly nutrient-rich reed marshes with saw-sedge developed along the edges of freshwater marshes. One explanation for the marine clay deposits in freshwater marshland might lie in the fact that the counter-pressure from the rivers in Flevoland was so great that the heavier saline and brackish water disappeared beneath the fresh water of the rivers in Flevoland.

Since Flevoland was connected by water to the sea, it has always been thought that there was a difference between ebb and flood along the coast of Flevoland. This has now been called into question on the basis of the botanical data. Willow swamps and reed marshes are typical of freshwater tidal areas. Though they did occur in the coastal zone, which was shifting inland, the low shores at Swifterbant were covered with riparian woodland, and alder was the most important tree species in the swamp. Alder has only limited capacity to withstand fluctuating water levels. In the winter it tolerates higher water levels because the tree is then dormant, but it cannot survive fluctuations in the summer, let alone differences in ebb and flood.

All in all, the botanical data have led us to assume that the coastal zone of Flevoland, which was shifting inland in the Late Atlantic, consisted of freshwater marshes, and that evidence for tidal movement was absent.

6.4.3 Lakes and large-scale peat accumulation in the Subboreal (circa 3700 – 1100 cal. BC)

The characteristic landscape features of the Subboreal in Flevoland are lakes and extensive mires. Layers of peat several metres thick accumulated during this period, not only in Flevoland, but in large parts of the Netherlands. However, fairly little is known about how the prehistoric peat landscapes of the Netherlands functioned. This is surprising, given the fact that peat accumulated in the Subboreal on a much greater scale than the sedimentation of clay during both the Atlantic and Subboreal.[599] In a sense, the lack of focus on peat is understandable. The clay deposits are still present below the surface, whereas most of the peat that formed in the Subboreal had by now disappeared, due to natural or man-made erosion, or because it has been cut and burnt as fuel.

Nevertheless, the huge expansion of the peat in the Subboreal, in terms both of area and of thickness (thus in volume) brought about major changes in the Dutch landscape and the way it was exploited. It therefore deserves a great deal of attention. Peat can only develop in a wet environment. At the same time, peat draws in water and retains it for a certain length of time, dramatically altering the hydrological processes in the landscape. In a sense, an expanding area of peat acts like a reservoir, particularly if raised bogs form. Though a lot of water enters the area, only a fraction of it drains away (see 6.3.6).

At the start of the Subboreal sea-level rise levelled off (and along with it the rise in the groundwater level in

598 Wiggers 1955; Ente *et al.* 1986; Menke *et al.* 1998.

599 See Van der Linden & Kooistra (2019) for the history of peat accumulation in the Holocene.

Flevoland), and there were large lakes in Flevoland. The largest and deepest of these lakes continued to exist. Most of the shallow lakes filled with vegetation. It is likely that most of them grew over from the shores inwards, as real aquatic plants generally produce little organic matter. Marsh plants, particularly reed, do however produce a lot of organic matter every year, which is converted to peat in water-saturated conditions. Reed colonises a body of water from the shore, however, with long offshoots that grow into the water. Only a few marsh plants (*e.g.* common club-rush and lesser bulrush) produce seeds that can germinate in shallow water, thus contributing to this process. Given this fact, it is likely that shallow lakes grew over from the shores inwards in the Subboreal. After a time, this would create a floating mat of peat. Progressive accumulation causes the peat layer to grow thicker, until it eventually reaches the lake bed.

Plants need nutrients from the environment to grow. Peat-forming plants draw nutrients from groundwater and surface water. If there are no minerals in the water, the environment will supply fewer nutrients. Minerals are absorbed by peat-forming plants and when they die they do not decay, so do not therefore release the minerals back into the environment. Instead, they remain in the peat. Development of peat without any supply of minerals via hydrological processes (surface water in the event of flooding, groundwater flows) thus depletes the nutrient content and causes the environment to become more acidic. The vegetation adapts to this. A nutrient-rich environment has different plants than an acidic, nutrient-poor environment. In short, therefore, we can say that the longer peat accumulation continues, the fewer free nutrients the peat soil will contain, and the more the vegetation will change.

Peat accumulation in the Netherlands, and particularly in Flevoland, had major implications for the landscape. If a peat landscape develops due to a rise in the groundwater level, a dry landscape will transform into a mire. Landscape development of this type occurred in the Atlantic. It did continue into the Subboreal, although in large parts of Flevoland the opposite occurred, with bodies of water (lakes) transforming into mires. As a result of these two developments, extensive mires developed consisting of a large variety of vegetation types, from which peat accumulated. In the expanding peat landscape the drainage of water stagnated. The origin of the water entering the area determines the nutrient content of the peat. Variation in the nutrient content of the water produced a variety of mire types in the peat landscape.

6.5 Three windows of observation

6.5.1 Zuidelijk Flevoland: Hoge Vaart-Eem microregion between 7000 and 4000 cal. BC

The site excavated at Hoge Vaart-A27 (location 9) consisted of a coversand ridge oriented northwest-southeast, the highest point of which lies some 5.60 metres below NAP. To the east, the ridge bordered the river Eem (fig. 6.26). The coversand ridge was inundated between 4400 and 4000 cal. BC. Traces of human activity there date to between 6900 and 4200 cal. BC.[600] The landscape underwent dramatic changes during the approximately 2500 years within which identifiable traces of human activity have been discovered on the coversand ridge and on the adjacent levee and in the channel, transforming from a dry inland coversand area to a freshwater marsh connected via a lagoon to the North Sea. The vegetation and fauna also changed radically during this period, mainly as a result of sea-level rise and the associated stagnation in the drainage of fresh water. The migration of cold-intolerant plants from Central and Southern Europe would also have affected the look of the landscape.

Exploitation phases 1 and 2: 7000 to 6000 cal. BC

At the transition from the Boreal to the Early Atlantic, the coversand ridge was high and dry, both literally and relatively speaking. The sea was some distance away and the water level lay far below the surface of the coversand ridge. During this period, the climate changed from continental, with hot, dry summers and cold, dry winters, to Atlantic, with more rainfall and less extreme summer and winter temperatures.

At the start of the Early Atlantic, pines still grew on a large scale (fig. 6.26a), as evidenced, among other things, by pine trunks found along the edge of the Eem valley. Pine cones found with one of the trunks could be dated to between 7451 and 6642 cal. BC.[601] In what sort of setting the pines grew is not clear, as no other botanical material from this period have been analysed. Given the developments elsewhere in Zuidelijk Flevoland, however, it is likely that there was open woodland with lots of pine, plus oak and birch, with an undergrowth consisting of heathland species. Hazel probably grew on soils containing more moisture and nutrients in the river valley and its flanks. In this dry landscape where lots of pines grew, hunter-gatherers dug pit hearths, one of which has been dated to between 6817 and 6477 cal. BC.[602]

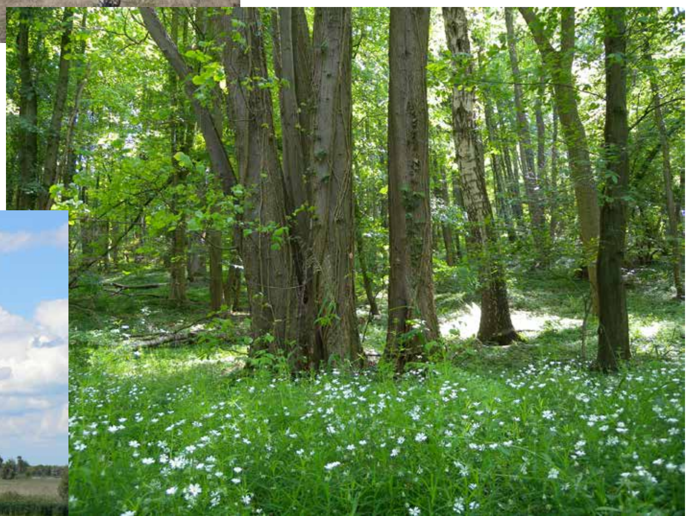
600 See chapter 4.

601 Peeters & Hogestijn 2001, 163, 8060 ±140 BP (GrN-25487).

602 7800±60 BP (UtC-5709).

a)

b)



c)

d)

Figure 6.26a-d: Impression of the vegetation during inhabitation of the Hoge Vaart-Eem microregion for a) the period around 7000 BC: open pine woodland (Nationaal Park de Hoge Veluwe, the Netherlands, photo: BIAX *Consult*/L.I. Kooistra); b) the period between 5500 and 5000 BC: deciduous woodland dominated by lime and oak (Savelsbos, the Netherlands, photo: Ecologisch Adviesbureau Maas); c) the period between 5000 and 4500 BC: nutrient-rich marshland (Oostvaardersplassen, the Netherlands., photo: BIAX *Consult*/L.I. Kooistra); d) the period around 4200 BC: stagnant water with water soldier (Nieuwkoopse Plassen, the Netherlands)(photo: J.A. de Raad).

Exploitation phase 2: 5500 to 5000 / 4900 cal. BC

The hunter-gatherers who made their fires in pit hearths on the coversand ridge over a thousand years later lived in an entirely different landscape. In the Eem valley there was water surrounded by swamps and carrs containing alder. On the coversand ridge there was deciduous woodland dominated by lime and oak (fig. 6.26b). Although lime commonly signifies dense woodland, the vegetation of the Hoge Vaart-Eem microregion was more open, as evidenced among other things by the pollen of species of the heath family found in the soil. The heath species may well have been a remnant of older vegetation from a period with a lower water level, when the coversand was more acidic and contained fewer nutrients as a result of leaching.[603] However, it seems that there was still an open type of woodland with oak and birch, and an undergrowth of heath, on the higher, drier and generally less nutrient-rich coversand soils to the south and east of location 9 (Hoge Vaart-A27).

Exploitation phase 3: 5000 / 4900 to 4500 cal. BC

At the transition from the Middle to the Late Atlantic the banks of the Eem were beginning to erode. People frequently visited the Hoge Vaart-A27 (location 9) site during this period. The landscape setting and wealth of botanical and zoological remains suggest that they lived on a spit of land in nutrient-rich marshland (fig. 6.26c). In the northwest the marsh made way for an area of open water (largely fresh water). In the south and east there was high, dry coversand. This transitional zone between land and water may have been attractive to humans for several reasons. The water provided good transport opportunities and the abundance and variety of plants and animals supplied a range of food and other resources that people needed to survive.[604] At the end of this period the coversand ridge was subject to regular flooding, which would have hampered continued habitation at this location.

Prior to being inundated, the coversand ridge was either covered with open deciduous woodland, or was an open area in mixed oak woodland fringed by a variety of shrubs that required large amounts of light. Over the course of 500 years, lime was the first tree species to disappear from this woodland landscape. Around 4500 cal. BC the area also became too wet for oak. As the environment grew wetter, the woodland gradually came to be dominated by alder, willow and birch. Club-rush species, reed and sedge species grew at the wettest spots in the marsh.

603 See section 6.3.4.
604 See chapter 4.

An open connection developed between the sea and the water-rich Eem valley. The remains of at least two seals, anadromous fish (eel and houting), sea fish that tolerate brackish water (flatfish and mullet) and one actual sea fish species (sea bass) are evidence for this connection.[605] Interestingly, only sporadic plant remains of saline marshes have been found, these mostly belong to the salt-tolerant freshwater species beaked tasselweed. Although there may be many reasons for the low proportion of marine fauna in the food spectrum, the virtual absence of brackish and salt marsh plants is a clear indication that marine influence was minimal in this microregion at this time. Furthermore, the evidence for freshwater marshland is overwhelming. It can be concluded from this that substantial amounts of fresh water must have drained into this area from the Gelder Valley and the Utrechtse Heuvelrug ice-pushed ridge.

This landscape at the boundary between land and water was home to a great variety of mammals. Some of them – red deer, wild boar, elk and squirrel – support the idea this was an environment rich in water and woodland. Though aurochs are now extinct, research has found evidence to show that these animals preferred river areas with nutrient-rich reed beds and meadows.[606] Marshes were also home to beavers and otters. Both beaver bones and gnaw marks on wood have been found.

The presence of horse bones suggests that, even at the start of the Late Atlantic, there were still open landscapes where woodland alternated with low-growing vegetation. The animals may have lived on the dry coversands to the south and east of the Hoge Vaart-A27 site, where there might still have been open oak and birch woodland with a heath undergrowth. The river Eem would have provided them with water. It is not impossible that horses co-existed with aurochs on the reed beds and meadows along the Eem, perhaps in the summer, when there was little to eat on the dry coversands and vegetation would have been abundant in the marsh.

Exploitation phase 4: 4300 to 4200 cal. BC

Around 4300 cal. BC sedimentation in the Eem channel ceased and the channel grew over with water soldier.[607] It seems likely that the drainage of water stagnated when a barrier formed in the Eem, possibly as a result of beaver activity.[608] The water soldier suggests the water was fresh to slightly brackish, and was either completely stagnant, or flowed only slightly. This species also indicates that the water was half a metre to two metres deep (fig. 6.26d).[609]

605 Laarman 2001.
606 Van Vuure 2005.
607 Gotjé 2001, 41 (Eem core-1).
608 Peeters 2007, 55.
609 Weeda *et al.* 1991, 232.

Figure 6.27: Hoge Vaart-A27 (location 9), post of a fish trap made of alder, probably from a beaver dam, as beaver gnaw marks can be seen on the tip (photo: Cultural Heritage Agency of the Netherlands/T. Penders).

Although the coversand ridge was no longer habitable, fish weirs with fish traps were still being placed in the open water. The fish weirs were made mainly of alder from the surrounding area. The wood was hardly worked, and small logs gnawed through by beavers were also used (fig. 6.27).[610] After a time the open water became grown over again, bringing an end to human activity at this location.

6.5.2 Oostelijk Flevoland: Swifterbant microregion between 8300 and 3700 BC

The Swifterbant microregion covers the area between Dronten to the east and the IJsselmeer coast (fig. 6.2). In the Late Glacial and Early Holocene there is evidence for a valley, through which the Hunnepe flowed from east-northeast to west-southwest (fig. 6.28). River dunes formed on either side of the river in this period, in a coversand landscape that lay six to eleven metres below NAP. Only a few of the tops of the river dunes extended higher, to four metres below NAP.

From 5400 cal. BC the coversand landscape, which had hitherto been dry, grew wetter as the sea level rose and the drainage of fresh water stagnated.[611] Peat initially developed, but from around 5000 cal. BC much of the area became covered by a large expanse of water. Although the river system was incorporated into this water body, its position could still be identified by the river dunes that flanked its original course. Marine clay was deposited under the water. The composition of the clay suggests that sedimentation occurred in calm conditions.[612]

Between 4300 and 4000 cal. BC some of the land became dryer. Channels cut into the clay and a landscape formed consisting of a main channel with side channels, levees and flood basins. The highest river dunes protruded above the clay and the lower-lying flood plain.[613] Despite the marine origin of the clay, very few brackish tolerant plants or remains of vegetation typical of saline marshes have been found.[614] The marine diatoms would have come from outside the area and were deposited with the clay. Many plant remains from freshwater marshes have been found, however, and alder grew in the flood basins. This means that the landscape at this period consisted of freshwater rather than saline marshes.[615]

Around 4000 cal. BC the channels and levees disappeared beneath a layer of detritus and gyttja, an indication that the area was again gradually being inundated by water on a large scale. Sea-level rise slowed down, however, and the water was colonised from the shoreline by marsh plants, signalling the start of peat accumulation and land formation in this microregion. Around 3700 cal. BC the river dunes were the last features to disappear beneath clay, gyttja detritus or peat.[616] In the eastern and higher parts of the microregion peat began to develop from around 4800 cal. BC, depending on the elevation relative to current NAP. At a certain stage, this peat would have been covered with water.[617]

Exploitation phase 1: 8300 to 7000 cal. BC

The oldest traces of human activity have been found on a parabolic dune in the east of the microregion, at the Dronten-N23 site (fig. 6.2, table 6.1, no. 25). The river dunes along the Hunnepe (fig. 6.2, table 6.1, nos. 26-30) were also visited by humans during this phase, though there is no known contemporaneous palaeoecological data.[618] Hunter-gatherers visited the dune at the Dronten-N23 sites with

610 Van Rijn & Kooistra 2001, 13.
611 De Roever 2004.
612 Ente *et al.* 1986.
613 Incl. Dresscher & Raemaekers 2010; Schepers & Wolteringe 2020.
614 Casparie *et al.* 1977; De Jong 1966; Van Zeist & Palfenier-Vegter 1983.
615 Schepers 2014a/b.
616 Incl. Dresscher & Raemaekers 2010.
617 Known as the Almere layer.
618 Devriendt 2013.

a)

Figure 6.28a-d: Impression of the vegetation during inhabitation of the Swifterbant microregion for a) the period between 8300 and 7000 BC: an open grassland area with heather and pine trees and a pine woodland in the distance (Nationaal Park De Hoge Veluwe, the Netherlands, photo: BIAX *Consult*/L.I. Kooistra); b) the period between 7000 and 6000 BC: heathland with isolated oak and birch trees on coversand (Vasserheide, the Netherlands, photo: BIAX *Consult*/H. van Haaster); c) the period between 6000 and 5000 BC: nutrient-poor fen woodland with mainly birch (Nationaal Park De Groote Peel, the Netherlands, photo: BIAX *Consult*/L.I. Kooistra); d) the period around 4300 BC: reed marsh as one of the nutrient-rich wetland types with clay underneath (Danube delta, Rumania, photo: BIAX *Consult*/L.I. Kooistra).

b)

c)

d)

some regularity, leaving evidence for flint working and pit hearths at the site.[619] The hearths contained mainly pine charcoal. At the end of this period deciduous species also appear in the charcoal spectrum, including oak, willow, birch and elm.[620] A concentration of carbonised hazelnuts from the beginning of the Boreal found in the depression of the dune suggests that hazel also grew there at that time.[621]

It is assumed on the basis of charcoal from Dronten-N23 (location 25), as well as data from elsewhere in Flevoland, that Middle Mesolithic humans in this microregion lived in a dry, relatively nutrient-poor coversand area on which open pine woodlands grew, with heath in the undergrowth (fig. 6.28a). During the course of the Boreal, more and more deciduous trees and shrubs began to grow there. However, heath continued to account for a substantial proportion of the vegetation, given its pronounced presence in palynological samples from the Early Atlantic (7000 to 6000 cal. BC).[622] Although no zoological material was found – due to taphonomic processes (see chapter 4) – it is not impossible that the open pine woodlands and heathlands were home to horses and red deer, as remains of these animals dating from later periods have been found in Flevoland.[623]

Exploitation phase 2: 7000 to 6000 cal. BC

Traces of Middle and Late Mesolithic hunter-gatherers from this period have been found on the parabolic dune (location 25) in the east of the microregion. The feature density on the site is low compared with the previous and subsequent exploitation phase. Like their predecessors, the humans of this period dug pit hearths, but activities associated with flint working seem to have disappeared. The charcoal spectrum from the pit hearths differ from the preceding phase, containing virtually no pine. The charcoal assemblage in these pits consisted of oak, willow and alder. From 6800 cal. BC the river dunes along the Hunnepe seemed to have become increasingly attractive for human exploitation. These dunes also show evidence for activities associated with fires in pit hearths.

Between 7000 and 6000 cal. BC the coversand area of this microregion appears to have featured dry, relatively high, nutrient-poor spots alternating with moist to wet, lower-lying, more nutrient-rich locations. This can be deduced from the palynological assemblages from the Dronten-N23 site (location 25), in combination with charcoal data.[624] Heathland with isolated oak and birch trees dominated the higher areas of coversand (fig. 6.28b). In the lower-lying parts, as well as in the river and brook valleys, the hydrology was probably more favourable for denser woodland featuring a greater variety of deciduous trees, including hazel, elm and lime, as well as oak. It is not impossible that heath formed part of the undergrowth here. Alder and willow dominated the woody vegetation in wet locations.

As in the previous phase, hunter-gatherers in this microregion lived in a dry but nevertheless hydrologically varied coversand landscape. Water was more widely available and the vegetation was diverse, which naturally gave the inhabitants a greater variety of plant and animal foods as well as resources.

Exploitation phase 3: 6000 to 5000 cal. BC

The parabolic dune at the Swifterbant N23 site (location 25) was frequently visited during this period. Pit hearths were being dug again, and the composition of the charcoal that they contained remained unchanged relative to exploitation phase 2.[625] Towards the end of this phase the environment probably became too wet for these activities. The river dunes in the west of the microregion (fig. 6.2, table 6.1, nos. 26-30) did remain in use, however. The landscape became more differentiated, continuing a trend that had started in the previous phase. Low-lying parts of the coversand landscape became so wet that fairly nutrient-poor sedge-reed marshes and marsh woodland with alder and birch developed (fig. 6.28c). These types of vegetation provided a basis for the formation of peat. The zone with deciduous woodland shifted to higher-lying areas of the coversand landscape as a result of the rise of groundwater. The woodland became more varied, and deciduous trees preferring a moist environment and slightly clayey subsurface, such as ash, grew on the coversand. The area of open heathland with oak and birch probably reduced in size, persisting only in the highest parts of the landscape.

In this phase, there was still a great variety of landscape types, although towards the end the coversand area had turned into marsh and only the highest coversand ridges and river dunes were dry and accessible all year round.

Exploitation phase 4: 5000 to 4300 cal. BC

Alder carr in the east of the microregion spread over the parabolic dune at the Dronten-N23 site (location 25). The last oaks, which had held out on the highest parts of the parabolic dune, disappeared shortly after 4800 cal. BC. As a result of the high water level, plant remains underwent little if any decay, and the dune was covered with peat. More open waters developed in the west of

619 Hamburg *et al.* 2012.
620 Kooistra 2012a.
621 Hamburg *et al.* 2012; Cunningham 2012.
622 Bouman & Bos 2012; Van der Linden 2012.
623 Incl. Laarman 2001; Zeiler 1997; Gehasse 1995.
624 Bouman & Bos 2012; Kooistra 2012c; Van der Linden 2012.
625 Kooistra 2012c.

the microregion. Only the higher river dunes were still visible as small islands in this wetland area and were only occasionally visited by humans.

The landscape altered radically during this phase. With the exception of the east of the microregion, a very nutrient-rich wetland developed, which was probably home to a large variety of fish, birds and mammals (fig. 6.28d). However, little is known about this phase, and these assumptions are based on finds from the following phase.

Exploitation phase 5: 4300 to 3700 cal. BC

When a marsh landscape with channels and flood basins developed in the west of the microregion around 4300 cal. BC, the inhabitants of the region began to exploit the levees. As we saw in chapter 4, the economic base of hunting, fishing and gathering expanded to include small-scale crop cultivation and stockbreeding. The mires in the east of the microregion near the Swifterbant N23 site (location 25) no longer appear to have been used for settlements, though the picture could be distorted here due to less intensive research being carried out at, and less favourable preservation conditions.

The high proportion of alder pollen and wood from both the levee and the main channel (fig. 6.2, table 6.1, no. 26), the levees of the side channels (figure 6.2, table 6.1, no. 27 & no. 30) and the flood basins, in the nutrient-rich marsh in the west of the microregion is striking.[626]. A range of wood types and the remains of other sorts of woody vegetation have been found in various places. This indicates the presence of a variety of trees, with willow, oak, ash, hazel, elm and poplar alongside alder. This spectrum suggests the various types of softwood and hardwood riparian woodland typical of river areas.[627] The composition of the woodland varies, depending on the location, the water level and the flow rate of the river. Willow is best able to withstand water currents and flooding, and is found in wet spots along the river.[628] In drier places, slightly higher up the bank, today's riparian woodland features black poplar as well as willow. If the ground level at a particular location rises through sedimentation, the composition of riparian woodland dominated by softwood species can shift more towards more hardwood varieties (*Alno-Padion*). Hardwood riparian woodlands include woodland along rivers growing on young, nutrient-rich mineral soils that occasionally flood. Nutrients are supplied on an incidental basis by flooding or via groundwater. Litter on the surface is rapidly converted to soil.[629]

The channels and some parts of the flood basins were dominated by nutrient-rich reed marshes and open water.[630] Given the abundance of beavers in the mammal spectrum, the gnawing marks on wood and the lack of dynamics in the water system, it is likely that beavers built dams in this marsh in order to create a safe habitat. Shallow parts of the flood basins may have developed into alder carrs over time.

During this final habitable period in the Swifterbant region, people lived in an exceptionally rich and varied freshwater marshland with an open connection to the sea in the west and access to the dry coversands in the east. This is evidenced not only by the botanical remains. Zoological remains also show a broad spectrum of fish, birds and mammals.[631] Remains of seal, fish that can live in brackish water and anadromous fish reveal the open link to the sea. However, the majority are from animals that are most at home in freshwater marshes, such as ducks, geese, otters, beavers and elk. The presence of horse and auroch bones is unusual. Aurochs are assumed to have been able to adapt to river meadows.[632] It is possible that horses came to this area occasionally from the dry coversand. This would presumably have been in the summer months, when the coversands dried out and water was in short supply. Equally, as areas of the marsh became drier, they provided nutrient-rich wet meadows and reed beds.

Over time, the Swifterbant region developed into a mire, and even the higher river dunes became too wet for habitation. The final visible features related to human activity date from around 3700 cal. BC, though this does not necessarily mean that people disappeared from the region entirely.

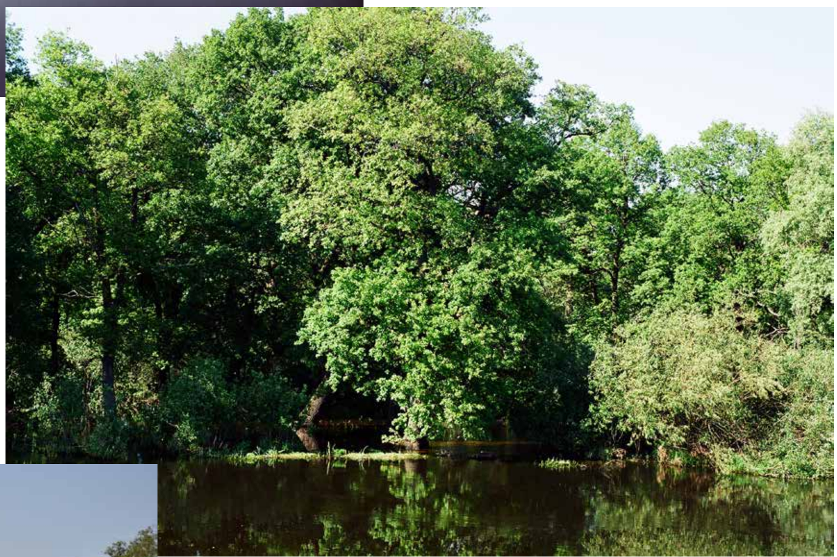
6.5.3 Noordoostpolder: Schokland-Urk microregion between 5000 and 1250 cal. BC

The Schokland-Urk microregion comprises mainly of the Overijssel Vecht river valley (fig. 6.2). The western boundary is the present-day IJsselmeer. The southern boundary is the Hunnepe. To the north and east are coversand landscapes that currently lie less than seven metres below NAP. The Early Holocene courses of the Overijssel Vecht and Hunnepe were flanked by river dunes formed in the Late Glacial and possibly also the Preboreal. In Flevoland the Overijssel Vecht flowed past four outcrops of glacial till that formed at the end of the Saalian and were covered by coversands during the Weichselian. The outcrops of glacial till – Voorst, Schokland, Tollebeek and Urk, from east to west – would have been very prominent hills in a low-lying coversand landscape in the first half of the Holocene. The river valley and adjacent coversand landscape

626 Casparie *et al.* 1977; De Jong 1966; Prummel *et al.* 2009; Raemaekers *et al.* 2010.
627 Van Beurden 2007; Margl & Zukrigl 1981. Wolf *et al.* 2001; Schepers 2014.
628 Van der Werf 1991, 242.
629 Stortelder *et al.* 1999, 302.
630 Schepers 2014; Van Zeist & Palfenier-Vegter 1983.
631 Prummel *et al.* 2009; Zeiler 1997.
632 Van Vuure 2005.

a)

b)



c)

d)

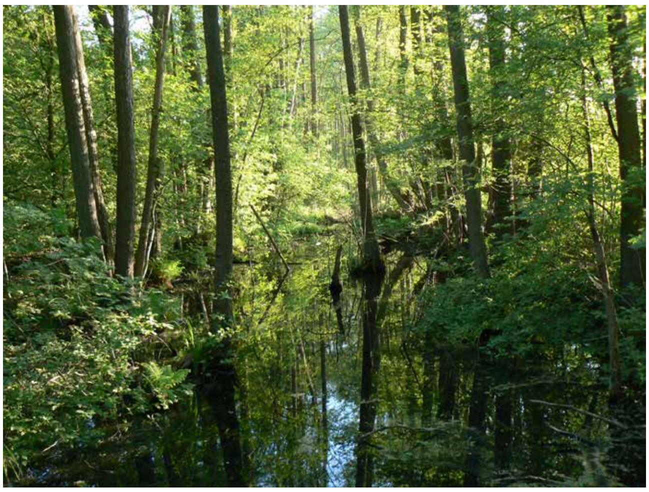


Figure 6.29a-d: Impression of the vegetation during inhabitation of the Schokland-Urk microregion for a) the period around 4000 BC: flooded landscape (Pripyat area, Belarus, photo: BIAX *Consult*/L.I. Kooistra); b) the period between 3700 and 3400 BC: hardwood riparian woodland in spring with an exceptionally high water level (levee of the Pripyat river, Belarus, photo: BIAX *Consult*/L.I. Kooistra); c) the period between 3400 and 1900 BC: sedge mire with common cottongrass (Kamerikse Nessen, the Netherlands, photo: BIAX *Consult*/L.I. Kooistra). d) the period between 1900 and 1250 BC: alder carr (Müritz National Park, Germany, photo: BIAX *Consult*/L.I. Kooistra).

were affected by the rising water level from 5000 cal. BC onwards. The area became a landscape featuring mires and lakes, through which the Overijssel Vecht meandered, and in which outcrops of glacial till, river dunes and higher coversand ridges in the south and northeast became dry 'islands' suitable for habitation. There are many traces of human activity in this microregion dating from the Late Palaeolithic (incl. Schokland-P14, fig. 6.2, table 6.1, no. 51) and the Mesolithic (incl. Urk-E4, fig. 6.2, table 6.1, no. 55) into the Bronze Age (incl. Schokland-P14, figure 6.2, table 6.1, no. 51).[633] Since there are barely any finds relating to the earliest human activity, the emphasis in this chapter is on traces of habitation that can be linked to the landscape. Although ten habitation and landscape phases have previously been identified on the basis of the archaeological and palaeoecological remains,[634] some phases have been combined here to reduce complexity.

Exploitation phase 1: 4900 to 3700 cal. BC: Swifterbant and the first half of the Pre-Drouwen

From 5000 cal. BC onwards the water level in the broad, shallow valley of the Overijssel Vecht rose, and over the following centuries the surrounding coversand flooded (fig. 6.29a). Initially, this rise in the water level caused peat to form on the coversand, but peat accumulation, that created overwhelmingly nutrient-poor sedge peat, did not keep pace with the rising water. When flooding occurred some of the peat washed away and clay was deposited under water. At first, there were very few marine elements in the clay. These did not appear until later.[635]

By around 4400 cal. BC, so much clay had been deposited that active channels were carved into the clay deposits in the west and a differentiation began to appear between the levees and clay-filled lower-lying depressions. From the levees and the dry Pleistocene coversands the depressions in the west became overgrown with reed marshes. Here, saw-sedge began to grow due to the increased amount of calcium-bearing clay. Further inland (towards the east) the reed marsh zones along the Overijssel Vecht were narrower, and there was a lateral transition to swamps containing alder, with some interim form of vegetation dominated by sedge species. The presence of swamps with alder makes it clear that, as in the Swifterbant microregion, there were no tidal influences in this part of the Noordoostpolder. The clayey levees of the channels became overgrown with willow. More varied deciduous woodland grew in places where the levees were broader and higher. In the south, just to the north of the Hunnepe, a high, east-west orientated coversand ridge with river dunes formed, providing a land connection to the coversand landscape further east until circa 4100 cal. BC. Until that time, the coversand ridge and the outcrops of glacial till of Schokland, Tollebeek and Urk appear to have been covered with deciduous woodland which initially also contained lime. However, a surprisingly large amount of grass pollen has been found in the sandy soil of the river dune at Schokkerhaven (location 52), suggesting that the woodland there was open rather than dense.[636]

During this period, humans mainly exploited the river dunes, outcrops of glacial till and the dry coversands in the northeast and south of the microregion. From approximately 4400 cal. BC they appear to have created more permanent places of habitation at a number of locations, including Schokland-P14 and Schokkerhaven-E170/171.[637] There was a broad spectrum economy, with crop cultivation and livestock breeding alongside hunting, fishing and the gathering of edible plants.[638] At Schokland (P14) people settled on the east side of the outcrop of glacial till on the levees of the Overijssel Vecht. The animal bone material and plant remains gathered during the excavations provide a glimpse of the landscape during the period for which there is evidence for human activity.[639] Beaver bones occur regularly, suggesting swamps or carrs. Fragments of water chestnut suggest there were shallow flood basins. Red deer bones and possibly wild boar bones indicate that the landscape also had drier wooded areas, although red deer are also known to spend a lot of time in wet areas. All in all, the faunal remains and remains of plant foods support the results from the palaeobotanical landscape study, which was largely performed outside archaeological sites.

Between 4400 and 3700 cal. BC the influence of the sea declined, although the water level continued to rise, to around five metres below NAP. The high coversand ridges of the microregion therefore lost their land connection to the dry areas of the north and east and, like the river dunes and outcrops of glacial till, they became 'islands' in the mire. The character of the mires gradually changed. The transition mires with sedges expanded, and bogbean grew in abundance there, a sign that the peat was becoming less rich in nutrients. In the west the reed fens that were richer in nutrients, and contained saw-sedge, continued to exist.

Exploitation phase 2: 3700 to 3400 cal. BC: Pre-Drouwen and Funnel Beaker culture

The start of this period was the development of the Bergen Inlet. A channel of this penetrated into the

633 Ten Anscher 2012.
634 Gotjé 1993; Gehasse 1995; Ten Anscher 2012, 507-536.
635 Wiggers 1955, 53-58.
636 Weijdema *et al.* 2011, 36.
637 Ten Anscher 2012, 510.
638 See chapter 4.
639 Gehasse 1995, 37-68.

Noordoostpolder via northern Noord-Holland and joined the Overijssel Vecht to the north of Schokland (fig. 6.29b). The strong dynamics in the channel caused peat erosion, and created a large lake by the Tollebeek outcrop of glacial till.

As a result of the new water regime and the supply of nutrient-rich water, reed marshes developed along the lake shores. The clay deposits around the tidal creek caused the reed marshes to become overgrown with saw-sedge. The old course of the river Overijssel Vecht to the west of the connection with the tidal creek grew over. The reduced dynamics and the declining supply of nutrient-rich water allowed sedge mires to develop, from which peat accumulated.

Though the course of the Overijssel Vecht altered radically and the connection with the Hunnepe, which must have been to the west of the Noordoostpolder, was severed, by and large the same landscape features continued to exist. The landscape remained attractive to humans for hunting and pasturing livestock, for fishing and for the collection of edible and other useful plants. The dry grounds on river dunes, outcrops of glacial till and the remains of dry coversand ridges were also used to cultivate crops.

Exploitation phase 3: 3400 to 1900 cal. BC: Late Neolithic

After the tidal channel broke through the coastline at Bergen, a period of stability in the landscape set in. The only change was in the water level, which rose, albeit less rapidly, from around five metres below NAP to just over two metres below NAP. The rising water reduced the area of habitable dry land. Around this time, for example, habitation at location 55 (Urk-E4) ended because the river dune grew too wet.[640] As the supply of nutrient-rich water via the sea reduced, the level of nutrients in the mire landscape of the region also declined. This process was probably exacerbated by the fact that less river water drained out of the region via upstream stretches of the Overijssel Vecht (eastern Gelderland, Overijssel and the southern part of the Drenthe Plateau) and its tributaries.[641] The mires of the Noordoostpolder reflected the changes in the hydrology. The mesotrophic sedge mires developed into oligotrophic raised bog. The fens with reed became alder carrs. The alder carrs then developed into birch carrs and, eventually, raised bog.

In this period people lived along the Overijssel Vecht, the Hunnepe, along triburaries and on the shores of the large lake (fig. 6.29c). Although the dry area was shrinking, people continued to live in this mires and use what the landscape had to offer. They cultivated crops on the increasingly scarce dry land, and used the surrounding sedge mires as pasture for their livestock. Wild animals, including red deer, aurochs and horses may also have grazed there. The wealth of game, birds, fish and wild plants would certainly have been a reason to continue living in the area, rather than relying exclusively on crop cultivation and livestock breeding. Nevertheless, this abundance of wild fare would have declined over time, as more and more raised bog developed and the landscape became more monotonous and nutrient levels fell.

Exploitation phase 4: 1900 to 1250 cal. BC: Early to Middle Bronze Age

From circa 2400 cal. BC flooding from the sea became a more frequent occurrence. Around 1900 cal. BC this also began to impact on the Noordoostpolder. Nutrient-rich water infiltrated the area from the west via the Overijssel Vecht. The adjacent peatlands eroded and marine clay was deposited in large parts of the microregion. The influx of nutrient-rich water containing clay undoubtedly led to a greater abundance of flora and fauna. Although it is likely that brackish water penetrated as far as the Noordoostpolder, it did not lead to the development of saline marsh vegetation. Fields of common club-rush and reed beds developed in shallow water with clay deposits. Common club-rush is one of the few marsh plants whose seeds can germinate under water. This species can therefore grow in the middle of a shallow lake. Reed, on the other hand, has to colonise the water from the shore. Eventually, they form floating mats which, at a certain point, are robust enough to serve as a subsurface for other species of marshes and mires and, eventually, for trees. After a time the thickening layer of peat becomes attached to the lake bed.

The Bergen Inlet closed between 1500 and 1350 cal. BC. The influence of the sea had not been felt in the microregion for several centuries. Open water became land and water nutrient levels fell. Fens again developed into raised bogs, though they did not cover the entire area. Large lakes continued to exist. Although the drainage of water to the sea stagnated, some river water will have entered from the east. It is not therefore likely that the raised bogs extended to the levees of the Overijssel Vecht and the route through the large lakes.[642] The levees of the Overijssel Vecht and the lake shores are more likely to have been covered with softwood riparian woodland, and locally with hardwood riparian woodland, and edged with alder and birch carrs and transitional mires with sedge species and reed. Evidence of this was found in the investigation at location 44 (Emmeloord-J97), where alder, birch, willow, poplar, ash, oak and elm were all found in

640 Peters & Peeters 2001, 20.
641 See section 6.3.6.

642 As suggested by Ten Anscher's (2012, 527) reconstruction for this period.

fish weirs and traps from the period 1900 to 1600 cal. BC (fig. 6.28d).[643] Bundles of reed had also been positioned against one of the fish weirs.

Towards the end of the Bronze Age there was very little Pleistocene landscape left at the surface. Only the outcrops of glacial till at Schokland and Urk and possibly river dunes along the Hunnepe in the south were suitable for habitation. New habitable locations may have developed on the floating peat along the edges of the lakes. Until they became attached to the lake bed, these mats moved up and down with the water level. Once they grew thick enough, and therefore more stable, they became accessible, and possibly habitable. We can therefore by no means exclude the possibility that people still inhabited the area, though there is little evidence of this due to later peat oxidation.

6.6 Conclusions

This chapter has presented an overview of landscape development in Flevoland between circa 12,500 and 1100 cal. BC, based on numerous investigations performed between the 1930s and 2014. Key factors in landscape investigations are developments in climate, texture of the subsurface and relief, hydrology and vegetation.

The Late Glacial (12,500 – 9800 cal. BC) marked the final phase of the last ice age. Warm periods alternated with cold periods. Flevoland had a coversand landscape that was still developing at this time. Three rivers flowed through the area, bringing in water from the wider region: the Eem in the south and the Hunnepe and Overijssel Vecht in the north. The subsurface was permanently frozen during the cold periods. The vegetation consisted of cold-tolerant species. In stadial periods Flevoland was covered with tundra vegetation, and in the interstadial periods it had open birch and pine woodlands.

Around 9800 cal. BC a protracted warm period began, known as the interglacial Holocene. In the Preboreal (9800 – 8200 cal. BC) coversand formation came to an end as the subsurface became covered with dense vegetation. River dunes continued to form only along the rivers. The vegetation in the Preboreal and Boreal (up to circa 7000 cal. BC) consisted mainly of cold-tolerant trees and shrubs. Contrary to the commonly held view, the landscape did not feature dense woodland, but rather open birch woodland, and later pine woods. In the coversand area local groundwater levels determined conditions, and peat developed in some places, depending on the extent to which water could permeate the subsurface.

From the Atlantic (7000 – 3700 cal. BC) onwards, the North Sea basin filled with water. This changed the climate from a land to a sea climate. The rising sea water caused stagnation in the drainage of water, which in turn caused the groundwater level to rise in Flevoland. This allowed peat to accumulate over large areas of coversand. Initially, the mires had fairly mesotrophic vegetation types (transitional mires) with features typical of raised bogs. Pines grew on the dry coversands until well into the Atlantic. Lime woodland occurred for only a short period. Initially the coversand were too dry and lacking in nutrients to sustain lime trees, and by the end of the Atlantic large parts of the coversand area were inundated with water and clay, and the conditions were too wet for this species.

Between 5500 and 4500 cal. BC the western part of Flevoland was inundated by water and clay of marine origin which was deposited under water. Although we have few botanical data from this period, we have the impression that Flevoland did not have saline marshes with halophyte plant species, and that there were no tidal movements there. Freshwater marshes developed in the low-lying parts of the Flevoland landscape. From 4500 cal. BC clay accumulated to such an extent that it protruded above the surface of the water, and the Eem, Hunnepe and Overijssel Vecht cut new channels through it. A river area with clay deposits became overgrown with eutrophic reed marshes, willows and alder carrs. Mixed deciduous woodland with oak grew on the levees of the rivers.

From 5500 cal. BC marshes, mires and lakes dominated the landscape of Flevoland. A mosaic of marsh and vegetation types ranging from nutrient-rich to nutrient-poor developed, from extremely wet clubrush and reed marshes to slightly drier alder carrs, depending on the level of nutrients in the environment. In the course of the Subboreal (from 3700 cal. BC) the Eem was transformed into an area of peat and lakes. The Overijssel Vecht still flowed from east to west through the landscape, but its course changed due to incursions from the Bergen Inlet in Noord-Holland. Less is known about the Hunnepe.

From 3700 cal. BC there was little dry land in Flevoland. It is likely that only the outcrops of glacial till at Voorst, Schokland and Urk were accessible by the end of the Subboreal (circa 1100 cal. BC). The levees of the Overijssel Vecht, Hunnepe and other peat rivers and brooks may still have been dry. Although no remains have been preserved, floating peat with riparian woodland may also have been accessible at that time.

643 Van der Heijden & Hamburg 2002, 34-40.