Species composition of an alluvial hardwood forest in the Dutch fluvial area under natural conditions (2700 cal year BP)

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SUMMARY

Differences in values of pollen types originating from upland tree species in two neighbouring and partly synchronous sections, located in the residual channel and the flood basin of a former Rhine distributary in the central Netherlands, reveal the species composition of an alluvial hardwood forest under natural conditions. Natural levees carried a forest with a high species diversity including *Fagus sylvatica*, *Corylus avellana*, *Tilia cordata*, *Betula* sp., *Acer* sp., *Carpinus betulus*, *Fraxinus excelsior* and *Pinus sylvestris*. These results embody the first aimed palaeo-reference system for nature development projects currently in progress on embanked floodplains in The Netherlands.

Key-words: alluvial forest, fluvial area, nature development, palynology.

INTRODUCTION

Nature conservation in The Netherlands is increasingly engaged in transforming agricultural lands into new nature areas (Gabor 1990, Joosten 1994). Especially for embanked floodplains, plans are prepared and in execution to re-establish 'near-natural wilderness areas' (De Bruin *et al.* 1987; Helmer *et al.* 1992; Projectbureau Grensmaas 1994; Iedema *et al.* 1994). Such so-called 'nature development' is assumed to be a less artificial and less expensive way to maintain biodiversity than permanent management of semi-natural and cultural landscapes (Baerselman & Vera 1989). Reference eco-systems for such natural landscapes are found in regions abroad with little human impact (actuo-reference systems) or in the geological record (palaeo-reference systems, During & Joosten 1992).

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In the past, several palaeo-ecological studies aimed at the reconstruction of landscape patterns and processes in the Dutch fluvial area for time periods prior to major human impact (e.g. Van der Wiel 1982; Van der Woude 1983; Hofstede *et al.* 1989, cf. Louwe Kooijmans 1995). These studies, however, do not combine spatial and temporal scales that are of special interest for nature development. A high temporal resolution is desirable to provide 'short-term' perspectives for developmental plans. A high spatial resolution of investigation, i.e. the reconstruction of fine-scaled vegetation patterns, is required to arrive at results compatible with present-day areas available for nature development.

This study presents the reconstruction of the hardwood forest vegetation which was present on the natural levees of a fossil river system in the Dutch fluvial area, while another study (De Klerk *et al.* 1997) focuses on the species composition and development of the wetland vegetation in the same study area.

RESEARCH STRATEGY

The Dutch fluvial area is characterized by a complex pattern of flood basins, alluvial ridges (consisting of residual channels flanked by natural levees) and associated crevasse splays. Vegetation of such landscape elements can be characterized by its (extra)local pollen deposition (*sensu* Janssen 1966, 1973) when samples are collected close to the pollen source. In contrast to such an (extra)local characterization of nearby landscape elements an entire landscape is characterized by the regional pollen deposition, which has a constant proportion of pollen types. Regional values are always lower than those of the (extra)local pollen deposition.

With this in mind, a research project aiming at the spatially fine-scaled reconstruction of the vegetation was initiated, based on an analysis of cores along a transect located around the Schaik alluvial ridge near Leerdam (Figs 1 and 2) traversing a flood basin and an alluvial ridge (Törnqvist 1989). The presence of plant taxa which grew close to the sampling site is traced by comparing local and regional pollen values along such a transect (cf. Janssen & Braber 1987).

Chronological control is essential for the reconstruction of vegetation patterns, i.e. the possibility of comparison of pollen assemblages of similar age. To that end three cores along the transect (Fig. 2: Oosterwijk I, residual channel; Oosterwijk II, transition alluvial ridge/flood basin; Oosterwijk III, flood basin) were studied preliminarily. These pilot studies were the basis for the present study, which concerns sections of cores Oosterwijk I and III, that were likely to be at least partly synchronous.

GEOLOGY OF THE STUDY AREA

The channel pattern of the Schaik system (Fig. 1) is described by Törnqvist *et al.* (1993). The lowermost clay layers in the flood basin (Fig. 2) are overbank deposits of the Schaik river system during its active phase. The peat above this clay layer formed after the end of river activity. The residual channel (core Oosterwijk I) contains two peat layers. The lowermost peat layer has been formed after major river activity ended. This layer has partly been eroded by renewed minor fluvial activity after which a second peat layer developed (Törnqvist & Van Dijk 1993). The uppermost clay layer in the cross-section was deposited by the Linge River, which became active around 2200 ^{14}C year BP (Törnqvist & Van Dijk 1993).
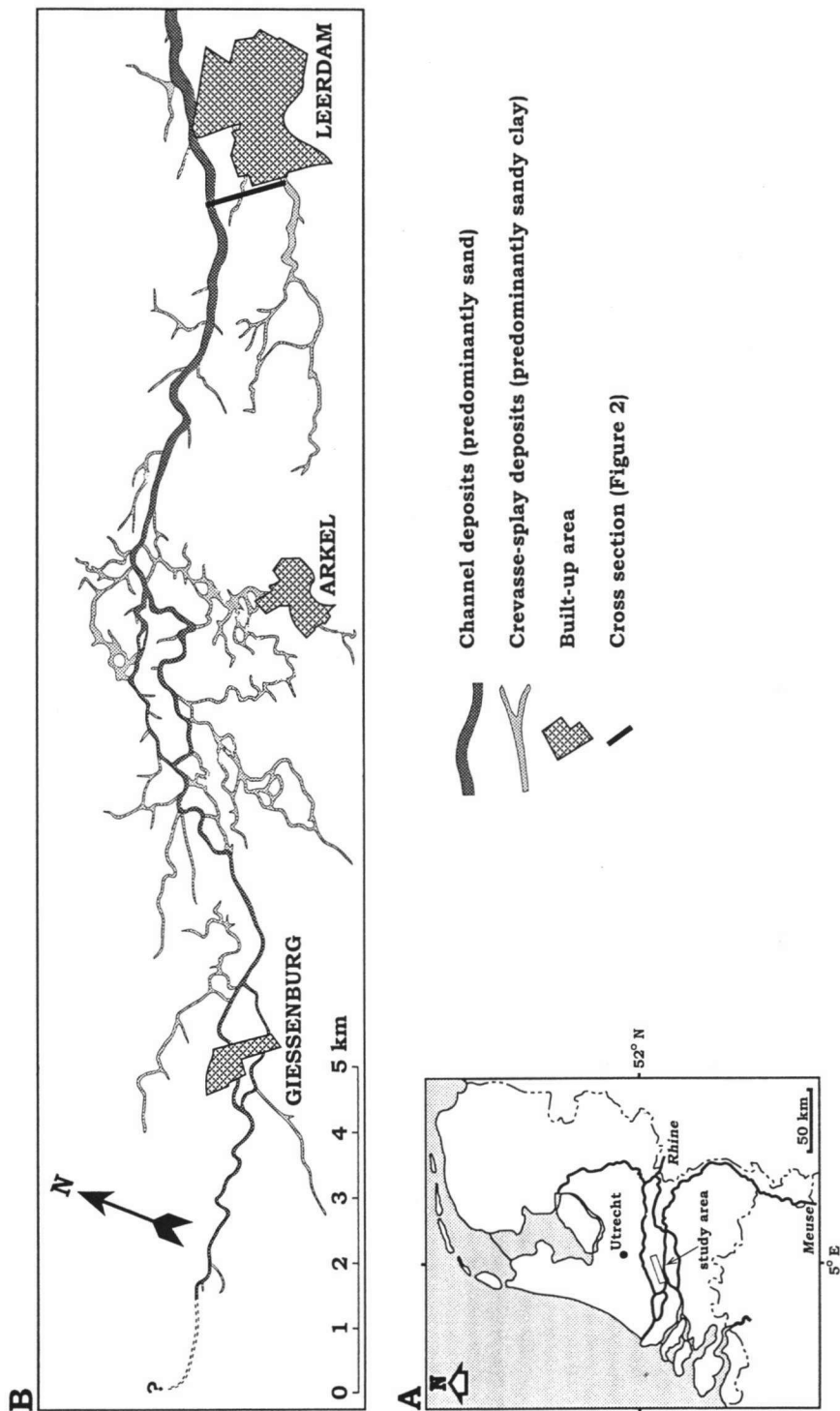
Fig. 1. Location (A) and near-surface geology (B) of the study area (after Törnqvist *et al.* 1993), with location of the cross-section presented in Fig. 2.
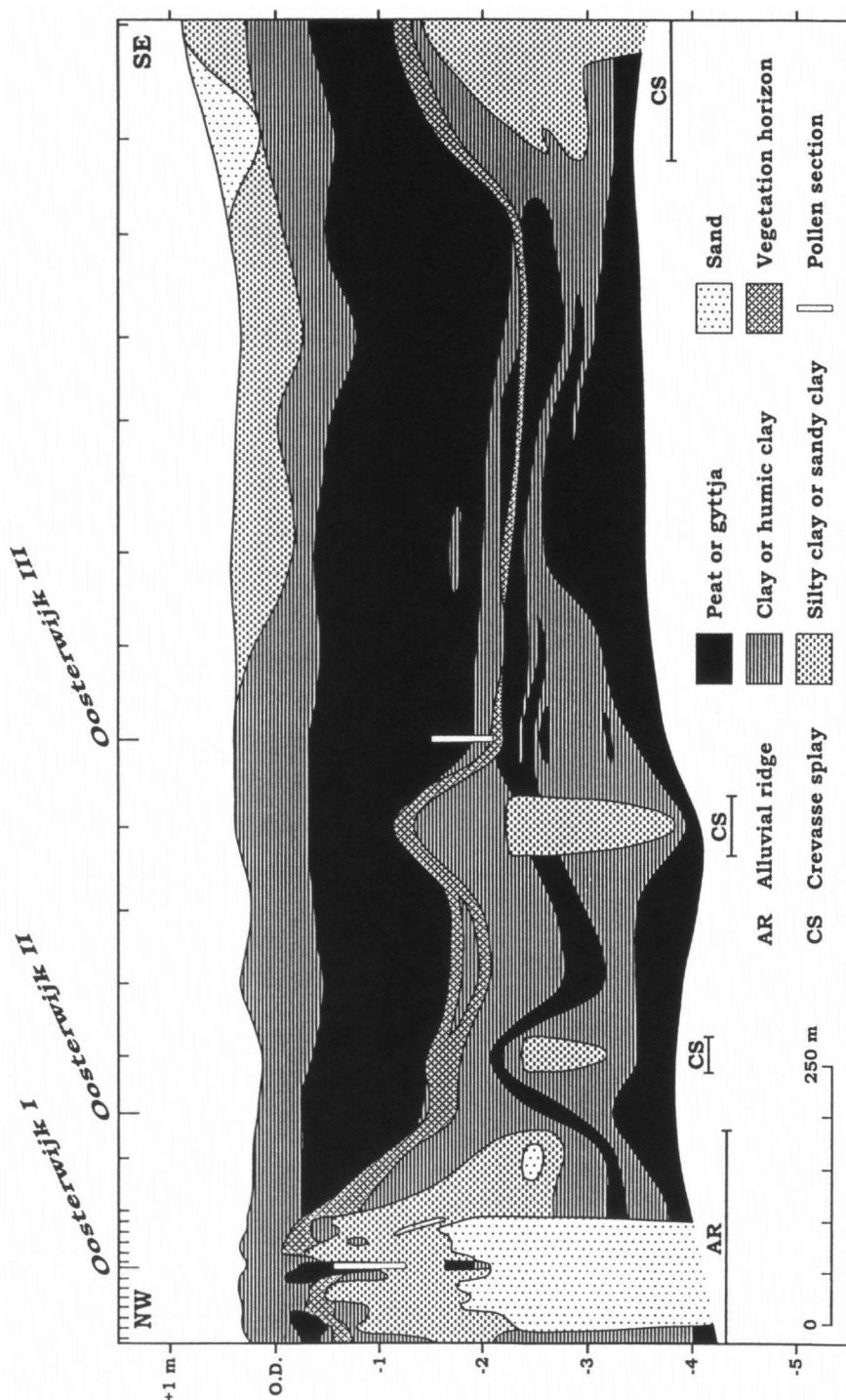
Fig. 2. Cross-section over the Schaik alluvial ridge and the adjacent flood basin (after Törnqvist & Van Dijk 1993). Indicated are the locations of the cores Oosterwijk I–III and the pollen sections studied.

FIELD AND LABORATORY METHODS AND POLLEN DIAGRAM CONSTRUCTION

Cores were taken with a gouge (60 mm diameter, Oosterwijk I) and a vibra-corer (70 mm diameter, Oosterwijk III) and sampled volumetrically with a sample interval of 1–4 cm. Sample processing included addition of a known amount of *Lycopodium* spores (in order to calculate pollen concentrations), boiling in 10% KOH, sieving (meshes of 120 μm), treatment with HF to remove silicates, acetolysis for 7 minutes and mounting in silicone oil, 2000 centistokes (Faegri & Iversen 1989).

Pollen and spores were identified with Moore *et al.* (1991), Faegri & Iversen (1989), and the Northwest European Pollen Flora (Punt 1976; Punt & Clarke 1980; 1981, 1984, Punt *et al.* 1988; Punt & Blackmore 1991; Punt *et al.* 1995).

The pollen diagrams were drawn using the programs TILIA 1.12 and TILIA GRAPH 1.18 (Grimm 1992). Pollen percentage values are expressed as percentages of the sum of pollen types supposedly originating from upland plants. All pollen and spores were given the suffix '-type' or '-group' to stress that these objects are morphological, not taxonomical entities. If more Dutch taxa are known to produce the same morphological type, these taxa are mentioned in the discussion, because these taxa will be the most probable producers of the sporomorphs encountered.

[14]C ages were obtained by AMS dating of seeds and fruits of telmatic plants in order to avoid reservoir effects or contamination (Törnqvist *et al.* 1992). The ages were calibrated according to Van der Plicht (1993) and Törnqvist & Bierkens (1994).

RESULTS AND DISCUSSION

Time correlation of the sections

Chronological control is essential for the reconstruction of vegetation patterns, because pollen assemblages of similar age must be compared. Since pollen zones are often time-transgressive, independent dating is necessary (Janssen & Törnqvist 1991).

The ^{14}C ages of the Oosterwijk I and Oosterwijk III sections (Table 1) show that most of the sections are not synchronous, with the exception of the upper part of section Oosterwijk III and the lower part of section Oosterwijk I. The ages cannot be extrapolated linearly to other levels in the cores since accumulation rates were not constant, as can be deduced from the concentration values of the pollen types included in the pollen sum (Fig. 3). Assuming that the influx of these pollen types at one site does not change substantially in the short time period studied, concentration values differ as a result of changes in accumulation rate (cf. Middeldorp 1982). The mean accumulation rate for the parts of both sections between the dated levels was calculated. Differences in the concentration values enabled an estimation of the accumulation rate of the parts of both cores above the 2700 cal year BP level. Now it was possible to calculate the age of the top sample of section Oosterwijk III (221 cm depth), which is 114 years younger than the dated level at 231 cm depth. The calculated level in core Oosterwijk I with the same age is at 114 cm depth. This method has not been applied to the bottom samples of the Oosterwijk I section because constant influxes can not be expected due to the presence of fluvially transported pollen (as will be discussed below). The time correlation of the two sections is shown in Fig. 4.

Table 1. ^{14}C ages of the Oosterwijk I and Oosterwijk III sections

Sample name	Coordinates and elevation above Dutch Ordnance Datum (m)	Laboratory number	Depth below surface (cm)	Dated material	^{14}C age (year BP)	Calibrated age (cal year ·BP)[1]
Oosterwijk I-2	132·995/ 434·040/ +0·15	UtC-3617	79–81	22 *Alisma plantago-aquatica* fruits	2220 ± 100	2216 (2337–2094)
Oosterwijk I-3	132·995/ 434·040/ +0·15	UtC-3597	125–127	1 *Alnus glutinosa* cone	2580 ± 60	2698 (2760–2563)
Oosterwijk III-3	133·270/ 433·620/ +0·35	UtC-3596	230–232[2]	10 *Alnus glutinosa* nuts	2600 ± 140	2692 (2853–2514)
Oosterwijk III-1	133·270/ 433·620/ +0·35	UtC-1133/ 1134/1135	255–258[2]	*Alnus* peat/1 *Sparganium erectum* fruit/6 *Oenanthe aquatica* mericarps	3225 ± 45[3]	3446 (3493–2514)

[1]Median and 1 σ confidence interval (in parentheses) as determined from the cumulative probability distribution of the calibrated age. [2]Not corrected for compaction caused by the use of a vibra-corer, so no actual field depths are given, but depths measured within the core. [3]Mean age as given by Törnqvist & Van Dijk (1993).
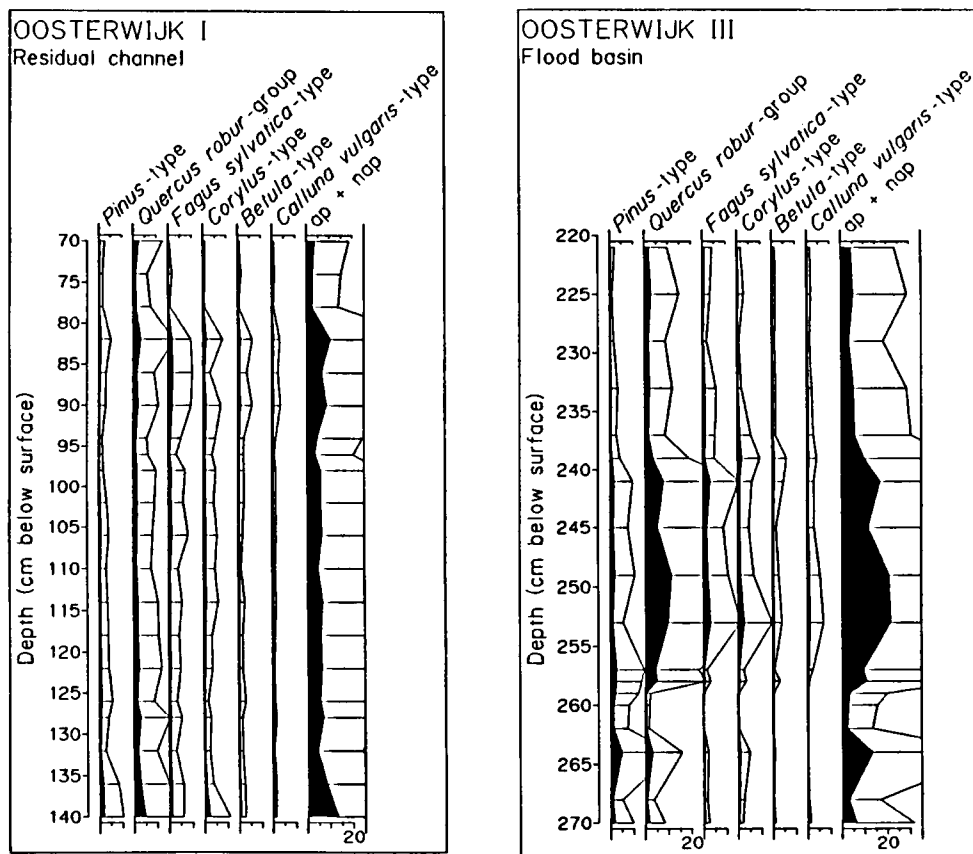
Fig. 3. Pollen concentration values (10^3 grains per cm^3) of the total number of grains of pollen types included in the pollen sum (AP+NAP) of sections Oosterwijk I (residual channel) and Oosterwijk III (flood basin). The concentration curves of the pollen types which are the main contributors to the pollen sum are also included to demonstrate that the trends shown are real trends present in the curves of all pollen types and not caused by only a few pollen types.

Fluvially transported pollen

The period before 3450 cal year BP in core Oosterwijk III (Fig. 6), when the clay layer below the peat was deposited, is characterized by high values of *Pinus-*, *Picea-* and *Abies-*type pollen and by the absence of pollen of *Plantago lanceolata-* and *Artemisia-*type. *Picea-* and *Abies-*type pollen must be of extraregional origin because both *Picea* and *Abies* were never native to this area during the Holocene (Lang 1994). These pollen types indicate fluvial activity, resulting in the deposition of clay with fluvially transported pollen of central European origin (cf. Van der Woude 1983).

The period before 2700 cal year BP in core Oosterwijk I (Fig. 5), when the clay layer below the uppermost peat in the residual channel was deposited, has relatively low values of water-transported pollen (*Picea-* and *Abies-*type), which points to only minor and local activity of the Schaik river system. This minor fluvial activity was too small to produce overbank deposits in the flood basin, as is shown by the absence of clastic sediments in the flood basin section (Oosterwijk III) in the period between 3450 and 2700 cal year BP.
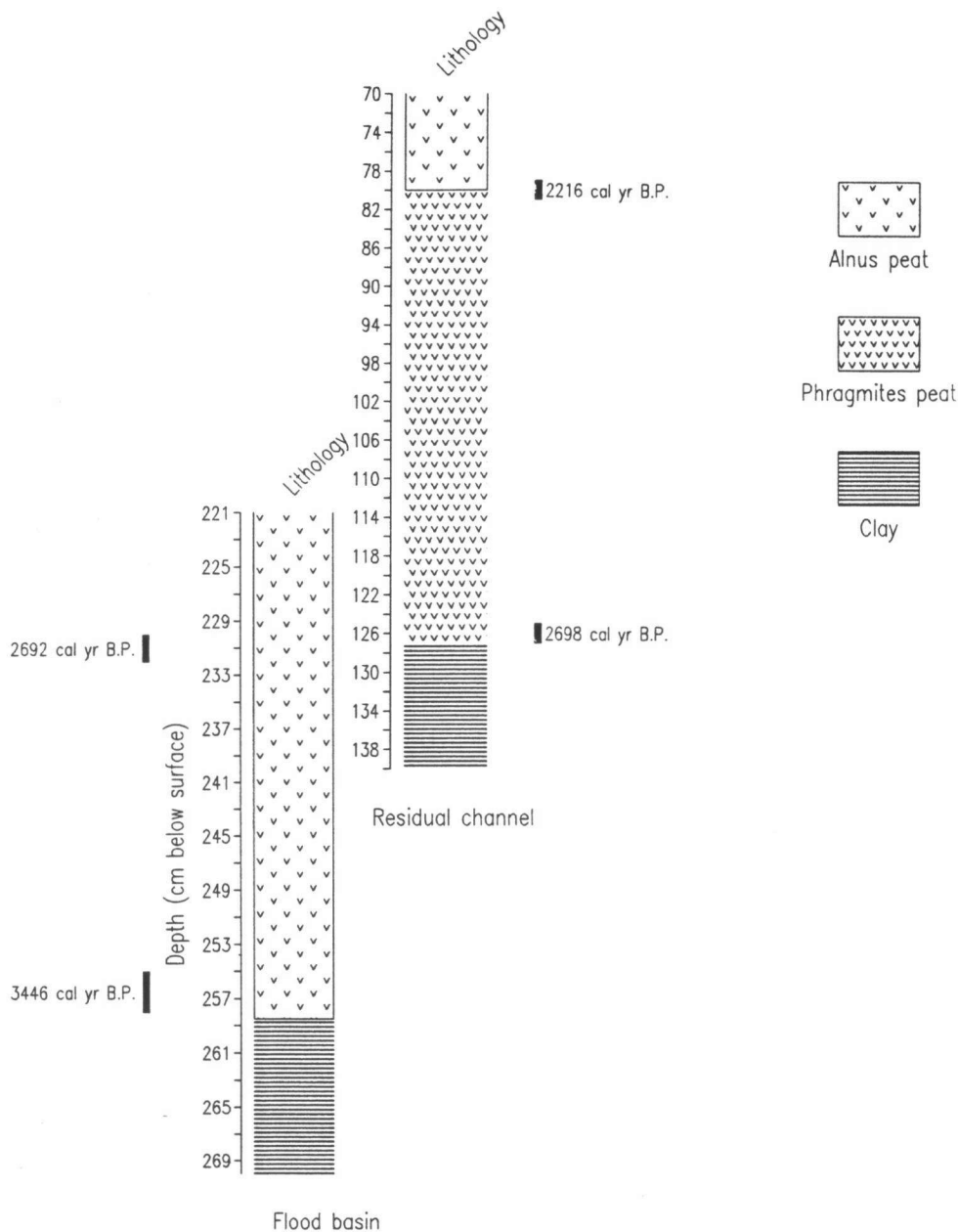
Fig. 4. Time-correlation and lithology of the cores of the flood basin (Oosterwijk III) and the residual channel (Oosterwijk I).

Reconstruction of the natural-levee vegetation

Around and immediately after 2700 cal year BP, the relative values of *Quercus robur*-group pollen (including *Q. petraea* and *Q. robur*) in the residual channel diagram (Fig. 5) are considerably lower, and those of *Pinus*-, *Betula*- and *Corylus*-type higher
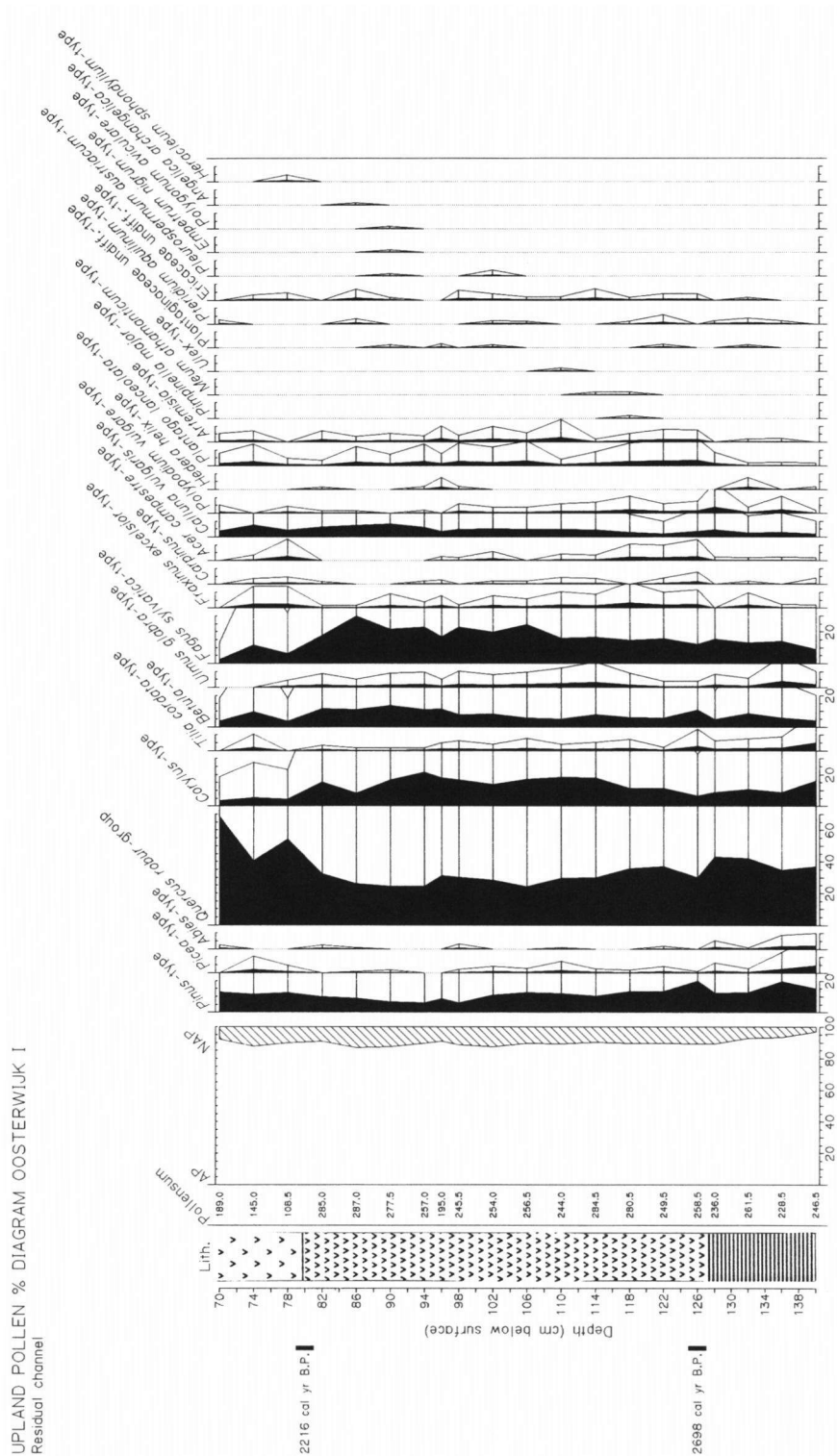
Fig. 5. Upland pollen percentage diagram of the residual channel (Oosterwijk I). The lithologic legend is given in Fig. 4.

than in the flood basin diagram (Fig. 6) (see also Table 2). These differences can be explained by: (A) extralocal deposition (*sensu* Janssen 1966, 1973) of *Pinus-*, *Betula-* and *Corylus-*type pollen from the natural levees into the residual channel coupled with regional values of *Quercus robur*-group pollen, or (B) regional deposition of *Pinus-*, *Betula-* and *Corylus-*type pollen, coupled with an extralocal source of *Q. robur*-group pollen near the flood-basin section (Oosterwijk III).

Hypothesis A   implies that *P. sylvestris*, *C. avellana* and *Betula* sp. must have grown on the natural levees of the residual channel close to the sampling site. In that case *Acer* sp., *Fraxinus excelsior* and *Carpinus betulus* will also have been present there, as is shown by the different relative values of *A. campestre-*, *F. excelsior-* and *Carpinus-*type pollen (Table 2).

Hypothesis B   implies that both sections are outside an extralocal pollen deposition trajectory of *P. sylvestris*, *C. avellana* and *Betula* sp., and that the flood-basin diagram contains extralocal values of *Q. robur*-group pollen. Such *Q. robur*-group pollen can only originate from a nearby crevasse splay (Fig. 2). This seems unlikely, since the the distance between the location of core Oosterwijk III and the nearest crevasse splay is probably larger than the short extralocal trajectory of *Quercus* pollen (cf. Janssen 1966). Furthermore, the crevasse splay was probably not present as an elevated topographic ridge around 2700 cal year BP. At present, the top of the crevasse ridge is only some decimeters higher than the 2700 cal year BP level in the peat. Increasing overburden loads and anthropogenic drainage will have resulted in a much stronger compaction of the Oosterwijk III section with peat and flood basin deposits than the area occupied by the clastic crevasse splay.

These hypotheses were tested by calculating mean influx values for the synchronous parts of the sections (Table 3). Mean concentration values of the synchronous parts of both sections have been calculated and, with the use of the accumulation rates, transformed to mean influx values. Higher mean influx values of a pollen type at one site indicate that the source of that pollen type must have been close to that site, i.e. within its extralocal deposition trajectory.

The results shown in Table 3 imply that around 2700 cal year BP *P. sylvestris*, *F. sylvatica*, *C. avellana*, *Acer* sp., *Betula* sp. and *Tilia cordata* must have been present on the natural levees close to the sampling site in the residual channel. Since *F. excelsior*-type and *Carpinus-*type pollen are continuously present in the residual-channel diagram and not in the flood-basin diagram these species might have been present as well, although their low mean influx values are less reliable. Considering the large pollen production and great dispersal capacity of *P. sylvestris* the differences in the mean influx values of *Pinus-*type pollen must be attributed to only a small number of pine trees on the natural levees. Other tree species (e.g. *Quercus* sp.) may also have been present on the natural levees, but only at a distance larger than their extralocal pollen deposition trajectories. Earlier studies (e.g. Van der Woude 1983, Hofstede *et al.* 1989; Törnqvist 1990, Brinkkemper 1991) have also mentioned part of these tree taxa as constituents of natural-levee vegetation in natural and semi-natural conditions (see Table 4). These studies, however, did not use a spatial scale comparable with this study, and reached their reconstruction by applying actuo-ecological knowledge on fossil relief patterns.

In contrast to most other studies, with the exception of Törnqvist (1990), the results presented here suggest that the 'wetland' taxon *F. excelsior* was also part of the natural-levee vegetation, probably at the marginal and hence lower parts of the natural levees.
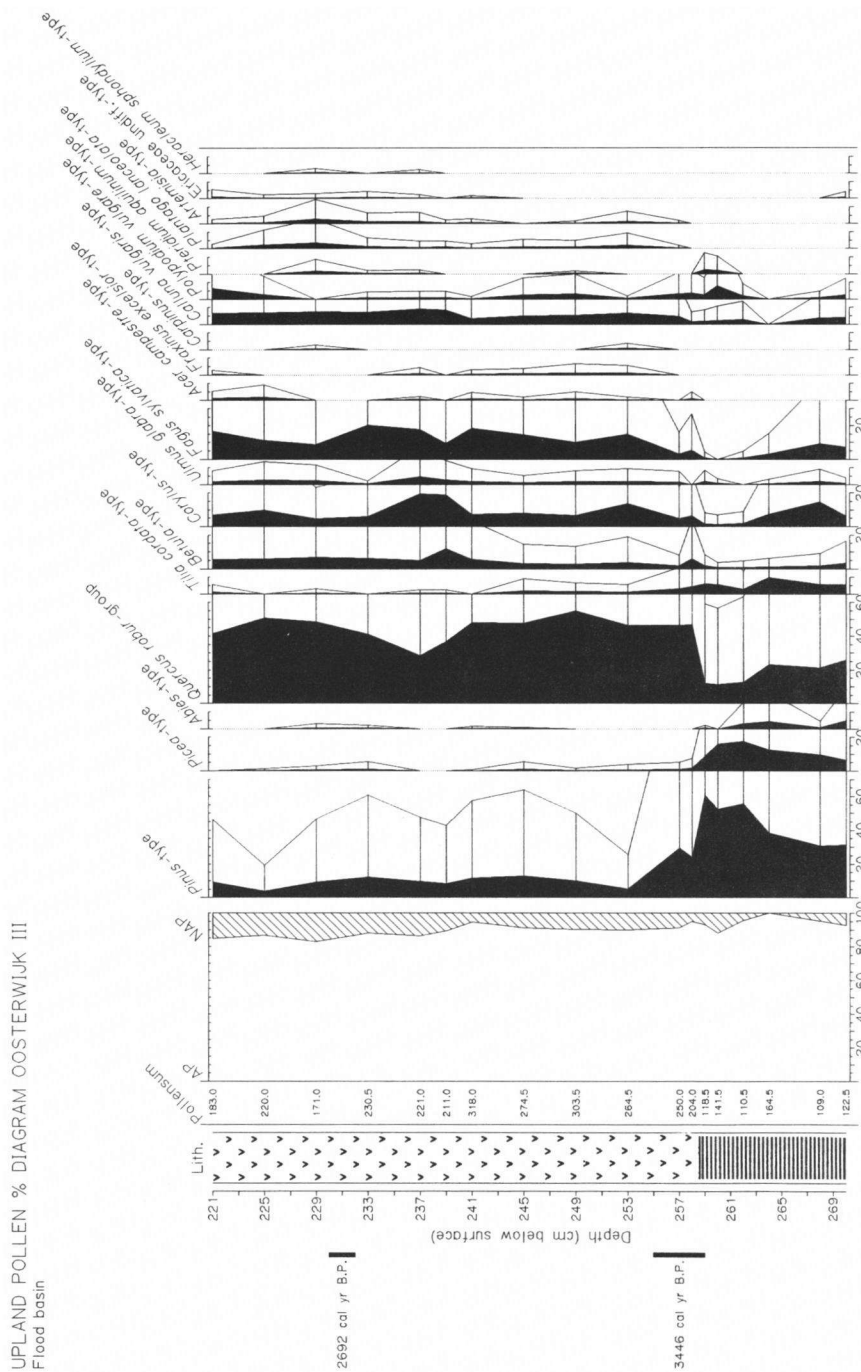
Fig. 6. Upland pollen percentage diagram of the flood basin (Oosterwijk III). The lithologic legend is given in Fig. 4.

Table 2. Relative values (% of upland pollen sum) of selected upland pollen types in the synchronous parts of sections Oosterwijk I (residual channel) and Oosterwijk III (flood basin)

	Oosterwijk I (depth interval 114–126 cm)	Oosterwijk III (depth interval 221–229 cm)
Pinus-type	10–20	4–9·5
Corylus-type	6·5–18	4·5–10
Tilia cordata-type	0·5–2·5	0·5–1·1
Betula-type	6–11	5·5–7
Fraxinus excelsior-type	2–3	0–0·5
Carpinus-type	0·5–1·5	0–0·5
Quercus robur-group	30–37	41·5–51
Fagus sylvatica-type	12–16·5	9–17
Ulmus glabra-type	1–3	1·6–2·5
Acer campestre-type	0·5–2·5	1–2
Artemisia-type	0·5–1·5	0·5–3
Plantago lanceolata-type	2–3·5	0·5–3·5

Table 3. Mean influx values (number of pollen grains $cm^{-2}\, yr^{-1}$) in the synchronous parts of the residual channel (Oosterwijk I) and the flood basin (Oosterwijk III)

	Oosterwijk I (depth interval 114–126 cm)	Oosterwijk III (depth interval 221–229 cm)
Pinus-type	88·22	29·57
Fagus sylvatica-type	94·86	52·27
Corylus-type	77·29	31·89
Betula-type	48·04	25·21
Acer campestre-type	11·77	4·6
Tilia cordata-type	8·66	2·15
Quercus robur-group	211·62	196·59
Ulmus glabra-type	10·78	9·44
Fraxinus excelsior-type	1·47	0·76
Carpinus-type	4·83	0·63
Plantago lanceolata-type	17·84	8·42
Artemisia-type	7·16	5·47
AP	5745·0	4033·2
NAP	662·2	704·4
Pollen sum	6407·2	4737·6

The mean influx values of *Plantago lanceolata*-type pollen indicate that *P. lanceolata* was probably also present at a distance from the residual channel shorter than its extralocal trajectory. *Artemisia*-type pollen shows similar and hence only regional deposition values at both sites.

Possible human impact

This study aims at the reconstruction of a natural vegetation and it is therefore relevant to know the extent of possible human interference.

Table 4. Trees ascribed to the natural-levee vegetation according to various authors

Period (^{14}C yr BP)	Van der Woude (1983) 7500–3000	Brinkkemper (1991) 2500–1500	Hofstede et al. (1989) 7000–4000	Törnqvist (1990) 2300–600	This study 2600
Quercus	x	x	x	x	
Corylus	x	x	x	x	x
Ulmus	x	x	x	x	
Fraxinus	x			(x)	(x)
Tilia		x	x	(x)	x
Fagus		x	x	x	x
Betula			x		x
Acer				x	x
Sorbus				x	
Carpinus				(x)	(x)
Pinus					x

The ratio AP/NAP may be indicative of human activity. If trees are felled to create space for agricultural activity, this will be reflected in pollen diagrams by lower AP and higher NAP values. Some minor fluctuations in the NAP curves in the flood basin diagram Oosterwijk III reflect more regional values than the residual channel diagram which is located within the extralocal trajectories of upland tree taxa.

Various pollen types associated with human activity may, according to Behre (1981), also reflect natural habitats. Exceptions are *P. lanceolata*-, *P. major/media*-, *Artemisia*-type and *Rumex acetosa*; the latter only when it is differentiated from *Rumex acetosa*-type pollen (including all *Rumex* sp.), which has not been done. Observed grains of the Cerealia undiff.-type must probably be attributed to the wild grass *Glyceria fluitans* (cf. Andersen 1979). Therefore this pollen type is included in the wetland diagrams (De Klerk *et al.* 1997).

This leaves only *Artemisia*- and *P. lanceolata*-type pollen as possible anthropogenic indicators. These pollen types are present in both diagrams with continuous low values. Janssen *et al.* (1995) consider similar low values to reflect regional deposition values rather than human impact on the direct surroundings of the sampling site. *P. lanceolata* may nevertheless have been part of the natural-levee vegetation near the sampling site, as has been discussed previously.

Some peaks of *P. lanceolata*- and *Artemisia*-type pollen are responsible for fluctuations in the NAP values: at 74 cm depth in Oosterwijk I and 229 cm depth in Oosterwijk III. Other levels with peaks of *Artemisia*- and *P. lanceolata*-type pollen include 126–118 cm depth in Oosterwijk I. The Oosterwijk III-229 level is synchronous with the Oosterwijk I-126 level, both dated about 2700 cal year BP, indicating that anthropogenic impact may have been reflected in the regional pollen deposition.

The question remains whether these trends are really indicative of human activity. In an outline of human activity in the western part of the Dutch fluvial area (Louwe Kooijmans 1974), various Iron Age settlements on the Schoonrewoerd alluvial ridge, located a few kilometres north of the Schaik alluvial ridge, are listed. No prehistoric settlement, however, is known from the Schaik alluvial ridge in the Leerdam area. Minor open and dry spots in the landscape may also be caused by grazing of large animals. A sample probably representing an excrement (De Klerk

et al. 1997) supports the presence of large wetland mammals in the Leerdam area at that time.

Since no human activities can be traced in the direct surroundings of the sampling site, vegetation propably developed under natural conditions.

CONCLUSIONS: SPECIES COMPOSITION OF AN ALLUVIAL HARDWOOD FOREST

The natural levees of the Schaik system carried a hardwood forest around 2700 cal year BP, consisting of *F. sylvatica, C. avellana, T. cordata, Betula* sp., *Acer* sp., *C. betulus, F. excelsior* and *P. sylvestris. P. lanceolata* also appears to have been present, indicating open spots in the vegetation, either caused by minor human activity or by natural grazing. Human activity, however, appears to have been absent or very restricted during the time period studied.

These results may be useful as a reference for the development of 'near natural' areas in embanked floodplains, although they should be interpreted with some care. The natural-levee vegetation reconstructed in this study was present after natural river activity had ended. During the time period studied the Schaik system was isolated in a large flood basin at a relatively large distance (up to 10 km) to the nearest active river systems (cf. Törnqvist 1994).

For further research it is recommended to focus on deposits more closely connected to a contemporaneously active river system.

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