# Woodlands of the past

## The excavation of wetland woods at Zwolle-Stadshagen (The Netherlands), I. Research objectives, concept and fieldwork methodology.

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### Abstract

Information on the vegetation- and landscape history is often limited, and interpretation of the available data is under discussion. To improve this situation an integrated concept is presented on how information about past vegetations can be gathered, analysed and interpreted and a comprehensive picture about the structure and development of past landscapes and vegetations can be gained. Archaeological field methods have been used to gather information about landscape (geology, micromorphology) and vegetation (ecology, palynology, dendrochronology) to come to a more complete reconstruction of the palaeo-environment. Hence it becomes possible to reconstruct the history of the vegetation and its structure, the growth patterns and population dynamics of key tree species and the influence of human activities on the woodlands.

This new concept has been applied to a buried woodland at Zwolle-Stadshagen (Province of Overijssel, The Netherlands) which was discovered during preparatory building activities. Many large remains of sub-fossil wood were found in a peat layer below a thick clay deposit. The wood remains were dated by using dendrochronology between 150 BC and AD 600. In cooperation with the Municipal Archaeological Service of Zwolle a multidisciplinary research group was formed to examine the options of an excavation in order to execute a fully-fledged interdisciplinary research. The results of this excavation are presented in five articles. In this first article the methodology developed for excavating a buried woodland will be presented and discussed, together with the sampling strategies employed in the various disciplines involved. In the following three articles the results will be discussed according to the disciplines applied, in the fifth the synthesis of the results will be given.

*Keywords*: interdisciplinary research concept, research objectives, fieldwork methodology, excavation, vegetation reconstruction, landscape reconstruction.

## Introduction

Recently ecologists, dendrochronologists and palynologists have raised questions about the interpretations of palynological datasets from archaeological and palaeo-ecological contexts for landscape reconstruction. Since the establishment of palynology at the beginning of the 20th century, the discipline has been used to gather information on the history of vegetations. To that purpose the palynological datasets were translated into plant formations and, with knowledge of the biotic landscape, into vegetations. However, the datasets generated by these disciplines do not provide enough information to answer the increasingly detailed questions about the structure and genesis of (pre) historic landscapes and the underlying causes of changes.

Not only have the questions about former landscapes and vegetation structures become more intricate, but there is also a revival in the discussion about the interpretation of palynological data. An important incentive to this revival comes from the publications of Vera (1997, 2002), who, on the basis of mostly palynological data, comes to the conclusion that the vegetation on the Northwest European continent during the Atlanticum was that of an open park-like landscape and not that of extensive dense forests. Several biologists, palynologists, botanists and archaeozoölogists disagreed with Vera's views (including Bremt et al., 1998; Zeiler & Kooistra, 1998), but arguments for and against could not be consolidated for lack of adequate studies. Palynologists verify their interpretations by comparing the palaeo-datasets with the counts of pollen rain in recent vegetations (e.g. Andersen, 1970 and 1973; Birks & Gordon, 1985; Gaillard et al., 1994; Hicks, 2001) and/or by linking historical and palynological information. However, there is a danger in the use of the recent and subrecent vegetation types as a reference for vegetations of the past because we cannot exclude the possibility that there may have been vegetation types which are non-existent nowadays.

Also dendrochronologists need more knowledge about the dynamics and structure of past woodlands in order to be able to analyse changes in the growth pattern of trees in terms of (changing) environmental en/or climate conditions. In Germany, Ireland and The Netherlands studies have been performed on the interpretation of the tree-ring patterns of sub-fossil 'bog' oak in terms of climate and site ecology. One objective of these studies is the use of ultra-long tree-ring chronologies of bog oak to reconstruct the natural variation of the climate during the Holocene (Leuschner et al., 2002; Spurk et al., 2002).

## Research concept

To get a more comprehensive picture about the structure and development of past landscapes and vegetations a group of researchers from different disciplines came together to formulate an integrated concept in which independent data sets from the different disciplines, i.e. archaeology, geology and micromorphology (geomorphology, hydrology, soil science), palynology (micro remains) and archaeobotany (macro-remains), dendrochronology are tested against each other. The concept has been put into practice by excavating a (natural) woodland with archaeological methods.

The importance of knowing the spatial distribution of sub-fossil woody plants in peat had already been perceived in the 1950s by the geologists and palynologists of the then Rijks Geologische Dienst (Geological Survey of the Netherlands), who recorded the presence of tree stumps and mapped them in the profile descriptions. (e.g. De Jong & Zagwijn, 1983).The first systematic study of spatial distributions of subfossil trees was carried out by Munaut (1967 and 1986), on a location southwest of Terneuzen (province of Zeeland, The Netherlands) where an approximately 5500-year-old submerged forest, with oak (*Quercus*) and pine (*Pinus sylvestris*) lay buried in the peat. His study comprised the mapping of the trees and palynological and dendrochronological studies. Leuschner et al. (1985, 1986 and 1987) reconstructed peat development and site hydrology and related it to growth and population changes of oak in wetland woodlands in Northern Germany. Lageard et al. (1995) recorded wood remains *in situ* three-dimentionally in order to get a better apprehension of the landscape and its use by men.

Inspired by these approaches the authors decided to perform excavations in areas that contain remains of past woodlands and to use archaeological field methods and techniques to collect and record data about the site and the vegetation.

We focus on areas with more or less unspoilt peat bogs in which plant remains, such as wood, seeds and pollen have been preserved *in situ*.

**The research objectives**

An excavation of a subfossil woodland presented itself in 2000. During preparatory work preceding building activities for a new urban development, called Stadshagen, northwest of the town of Zwolle, many large remains of subfossil wood were found in the subsoil, a peat layer preserved below a thick clay deposit. The extent of the area was such that a buried woodland could be expected. Dendrochronological dating of three tree remains indicated that this woodland dates to approximately 1 BC/AD 1, but it was expected that the trench profiles would contain information on the development of the vegetation over a period prior to these woodlands. Archaeologists of Zwolle were particularly interested in the period from 800 BC until AD 1000 in relation to the disappearance of the Bronze Age habitation in the area around Zwolle. Van Geel et al. (1996 and 1998) have proposed as a cause a change to a colder and wetter climate, not only in this part of the country but also elsewhere in low lying regions in The Netherlands. The excavation might give insight into the local conditions in relation to the interaction between the local landscape and the occupation history of the area and whether or how people may have exploited the woodlands in this period.

In the summer of 2000 the Archaeological Service of Zwolle and the authors cooperated in the excavation of the site Zwolle-Stadshagen (Fig. 1), taking the insights gained by notably Munaut (1967, 1986), Leuschner (1985, 1986 1987) and Lageard *et al.* (1995) as a starting point. The participating disciplines in the study were (1) physical geography and soil science, in order to assemble information on the abiotic landscape development and the hydrology, (2) ecology including palynology and wood research, to gather information on the vegetation including its structure and development, and (3) dendrochronology, for the absolute dating of the wooden remains, the population dynamics of the key species in the woodland and for information on the impact of either local or regional factors that influenced tree growth. Each discipline provides independent data and interpretations of the data on the structure, composition and changes in the vegetation, and each discipline tests the interpretations of the others.

The following research objectives were formulated for the excavation of Zwolle Stadshagen:

Description of the local vegetation of the past, its structure and its development
Interpretation of the occurring vegetation types in relation to the environmental/ abiotic (geology, geomorphology, soil and climate) and biotic (flora, fauna and people) factors.
Evaluation of the integrated concept and its results in comparison to the traditional approach in reconstructing the palaeo-landscape and vegetation.

## The fieldwork methodology

### *The preliminary survey*

In order to evaluate the potential of a terrain for palaeo-ecological research and the feasibility of the integrated concept as well as to collect information to plan the excavation a preliminary survey has to be performed. A preliminary survey serves several purposes. It makes it possible to (1) establish the homogeneity of the area, (2) determine the variability in thickness and relief of the peat layer, and the depth of the wood macrofossils, (3) assess the state of preservation of the organic material (wood, seeds and pollen) and (4) give insight in the spatial distribution of the tree remains and the respective absence or presence of the various tree parts, such as trunks, branches, tree tops and root systems. Advance knowledge of the homogeneity of the terrain and the depth of the peat and wood macrofossils is important to determine the size of the excavation area and to plan the number of excavation levels. Information on the state of preservation of the various botanical materials gives an indication whether the material is well enough preserved to answer the questions put in the study.

Two days were available for the field survey in Zwolle-Stadshagen. The constructors had prepared a terrain of three hectares for building purposes by removing the topsoil and the underlying clay sediment. By doing so the peat layer with the many wood remains became visible on the surface. The wood remains seemed rather homogeneously distributed across the whole terrain. Considering the size of the terrain and the available time for a preliminary survey, two parallel trial trenches of 15x80 metres, 110 meters apart from each other, were selected and examined (Fig. 1, trenches 1 and 2). On the four corners of each trial trench the thickness of the peat layer was measured with an Edelman soil auger. The thickness varied from 12-35 cm. Wood remains were visible in the entire peat layer. No wood remains were found in the underlying cover sands or in the overlying clay cover.
All 167 wood macrofossils found within the two trial trenches were numbered and the three coordinates recorded. From trunks or parts of trunks the coordinates were determined at both ends, from smaller fragments and root systems just one measuring point was selected. The measurement for the Z-coordinate, which in The Netherlands is expressed in metres above and under sea level (formalized in Dutch Ordnance Date, referred to as O.D.), was taken on top of the wood. The location and orientation from each wood macrofossil has been recorded and a short description was made on the morphology, including information on dimensions, the origin of the wood-identification and/ or dendrochronological sample with respect to its location on the

tree (trunk, tree top, branch, roots, unidentifiable part) and the presence and location of lateral branches. All wood macrofossils were sampled for identification and 34 oaks and three ashes were sampled for dendrochronological investigation.

In view of the rather homogeneous distribution of the wood remains across the terrain it was decided to excavate an area of approximately 1000 square metres. Because the layer of peat was relatively thin, the number of excavation levels was restricted to just one. The state of preservation of the botanical remains was estimated by the state of preservation of the wood, which was in general reasonable. Not only the durable oak (*Quercus*) had been preserved, but also ash (*Fraxinus excelsior*) and alder (*Alnus*). On a number of oaks the outermost sapwood rings were still present, indicating rather good preservation. The presence of sapwood rings allows the year of death of the trees to be established with more precision. The preliminary dendrochronological results confirmed the earlier results whereby the woodland was dated to approximately the BC/AD change. Unfortunately, it appeared that in general only fragments of trunks, branches and root systems were preserved

Despite the lack of morphological information, the abundance of the wood remains and the wealth of potential information from the other disciplines justified an extensive research by excavation. As the stratigraphy of the surveyed area had been partially lost by the stripping of the terrain during the preparations for the future building activities, the decision was taken not to spend more time on the surveyed area but to focus on an area just north of the two trial trenches where profiles were still intact (see Fig. 1).

*The excavation*

The intended excavation area of 1000 square metres was divided into four trenches of 280, 495, 275 and 223 square metres respectively (Fig. 1, trenches 3, 4, 5 and 6). The form and precise size of the trenches depended on the available space on the building site. The excavation campaign took a total of six weeks with an average manpower of three people. With the help of a bulldozer an excavation level was made on the transition of the clay cover and the peat. Only at the spots where trees were lying on top of each other, a second level was made by hand.

To assess the stratigraphy of the soil layers, a three-metre grid was laid out in each of the trenches. The O.D. value was measured at each corner point of the grid. At the same location the thickness of the peat layer was measured which also enabled a reconstruction of the relief of the Pleistocene coversand surface.

Apart from these measurements related to the genesis of the landscape, the profiles in the trench walls were studied and locations were selected to collect samples for micromorphological and palynological research. The criteria for the selection of the right location were 1. A soil profile and stratigraphy that was representative of the site, 2. The presence of a root stump connected to an oak with dating potential, 3. By taking samples for micromorphological and palynological research at the same location, it will be possible to subsequently link the results and to establish the relationship between vegetation development and environmental factors. To complete the picture on the vegetation development, soil samples with a volume of 5 litres were taken for analyses of seeds and insects/mites. The seeds provide information on the (very) local plant growth, and insects and mites, many species of which are often restricted to narrowly delimited ecological niches, generate further information on the structure of the vegetation. Samples for both types of analyses were taken close to the tree trunks. The underlying idea was that the soil in which a tree trunk rests, dates from the period in which the tree fell down.

The tree trunks and all other wood remains (Fig. 2) were numbered and the three coördinates recorded as described for the trial trenches, and mapped on the field drawing. From root systems the diameter was measured. When present, the orientation of the root system and the top of the tree was recorded. There are two ways in which the tree could have fallen into the peat. Trees can be wind thrown, in which case the tree pulls the shallow root system during its fall out of the ground (Fig. 3a). The other possibility is that the tree breaks off above ground or rots away and the root system stays behind *in situ* in the ground (Fig. 3b). If root systems have stayed fixed in the ground, information can be gathered about the level in which the trees germinated and about the speed at which the peat grew during the lifetime of the trees. In the case of thrown trees this information is not available. One can get an indication of the level of the ground surface at the time when the tree fell down, as that is the layer on which the trunk rests. Those parts of the trees that were found horizontally on the surface were carefully excavated by hand to determine the total remaining length and diameter of the wood and to describe the wood remains in more detail. Tree stumps *in situ* were excavated in quadrants. By recording all wood remains on the field drawings three dimensionally, the vegetation structure and spatial distribution of the various tree species was visualized (see Kooistra, L.I., et al., 2003, III, this issue). The field drawings also provided data on the orientation of the fallen trees.
Apart from recording on the field drawings, description forms were filled in separately for each piece of wood. Metric features such as lengths and diameters of trunk and branches were noted, as were the morphological features such as tree parts,

form and size of root systems, the presence and location of branches on the trunk. Moreover, notes were taken on the presence of cutting- or grazing marks on the wood. Additional comments were made on the suitability of the samples for dendrochronological analyses and/or wood identification. Photographs were taken of every piece of wood or groups of wood remains. The field drawings provided information on the position and distribution of the wood remains, whereas the description forms were primarily meant to register detailed information on the morphology of the individual wood macrofossil. Morphological characteristics contain important information on vegetation structure and disturbances. Trees lacking lateral branches along the whole length of the trunk most probably grew in a closed type of wood. Root systems that show more than one off-shoot point to the possibility that either shoots were eaten by animals at an early stage or that people cut the stems causing the root system to form new shoots. The morphology of the root systems also provides information on the growing conditions of the trees, e.g. shallow root systems indicate a high groundwater level.

## Evaluation of the fieldwork methodology

*Preliminary survey*

There are various methods of performing a preliminary research. In the case of trial trenches the topsoil is removed till the level of the sub-fossil trees. The tree remains are three-dimensionally mapped, the outer appearance of the remains is described and the sampling for wood identification and dendrochronological investigation is

restricted to the numbers needed to get a general insight into the range of species and the dating of the wood fossils. The soil profile and stratigraphy is studied in the walls of the trenches and by soil augering. On the basis of these datasets including the information on the state of preservation of the organic material a decision can be taken as to the value of the terrain for further research.
A second method which has been used in the past, is the so-called probing method. The area to be studied is divided into a grid and at each intersection a thin metal rod is pushed into the ground. Resistance felt in the ground indicates the presence of wood. By systematically inspecting the terrain, the density of wood macrofossils can be estimated. Initially the method was used to detect subfossil oak for dendrochronological research. It became clear though that it was not possible to discover the remains of softer, less durable wood species such as alder and birch. This method is not recommended for determining the density of wood remains irrespective of species. At the second site where a natural subfossil woodland was excavated, Den Haag-Ypenburg, the probing method has been tested on an area measuring 300 square metres divided into a 1 x 1 metre grid. By the probing method resistance was felt on 40 of the 361 separate probing points, indicating the presence of 40 wood macrofossils, by excavating the same area approximately 80 wood macro remains were uncovered. Another disadvantage of the probing method is the limited depth of one to one and a half metres that can be reached with the probing rod. In Den Haag-Ypenburg the compact structure of the peat prevented the rod from penetrating deeper than 0.75 metres. Wood macrofossils lying at a greater depth could not be detected.

In Zwolle-Stadshagen the method of trial trenches was used for the preliminary survey of the terrain. There were some departures from the original concept due to the

fact that the site had been previously been stripped in order to prepare it for building. The excavation level was not determined on archaeological grounds but happened to be the depth left by the stripping, which fortunately happened to be exactly the right one. The second point is that in most cases trial trenches are some metres wide and are laid out and spread over the total area to be studied. The advantage of this is that the whole of the site is surveyed and that the profiles in the trenches will provide information on the stratigraphy across the whole area. However, the open-lying surface in Zwolle-Stadshagen extended across an area of three hectares and therefore there were no profiles available showing a complete stratigraphy. This was the reason why the excavation was done in a terrain just north of the trial trenches (Fig. 1). All wood macrofossils in the trial trenches were included in the final study as well as all suitable oak remains in the dendrochronological research.
The experiences acquired in the preliminary and excavating phases of the sites of Zwolle and Ypenburg lead to the strong recommendation that the potential of a terrain for research on palaeo-vegetation reconstruction in its environmental context should be tested by means of trial trenches.

*Excavation*

The peat layer in Zwolle-Stadshagen was relatively thin and only one excavation level was required. The state of preservation of the organic material was such that only parts of tree trunks and root systems were left, except for those located deeper in the soil. These root systems were visible in the field as an irregular circle of wood remains with an empty spot in the middle where the trunk had been attached. Due to the compression of the peat by desiccation and compaction by the upper layers, the wood macrofossils, which would originally have been deposited in different levels, ended up in one and the same. This is the reason why the root systems are not recorded three-dimensionally according to the method of Lageard, Chambers and Thomas (1995). Consequently the information on the vegetation structure on the Zwolle site is less detailed.

Although the strategy designed for the fieldwork and the accompanying field registration forms functioned fairly well, two critical remarks have to be made. During the processing of the data recorded on the registration forms (see Kooistra, L.I., et al., 2003, III, this issue) it became clear that the information was not uniform. This caused problems with the digitalisation of the data. The tree remains are to be considered as archaeological features and treated as such. They should be drawn to scale on graph paper, with particular details as to the presence and position of lateral branches, tops and/or roots, the locations where the samples for wood identification and dendrochronological investigation have been taken, etc. The relevant characteristics of each feature should be described on an additional form. The design of the form should be in conformity with the digital data structure.

The second critical remark pertains to the sampling strategy. In Zwolle-Stadshagen the samples for the analyses of seeds and insects/mites were taken next to the tree trunks. It was not possible, however, to link these data to the palynological and micromorphological data provided by the samples from the profiles. To tackle this problem the sampling strategy was adjusted in the excavation of the subfossil woodland of Den Haag-Ypenburg in the winter of 2000/2001. Here, apart from the single samples taken next to the tree trunks, two square columns were prepared, at two different locations, each measuring 1x1 metre and containing the stratigraphic record of the site. First palynological and micromorphological samples were taken, then the columns were sampled from the top down in layers of three centimetre for the analyses of seeds, insects and mites. The thickness of three centimetres of the layer is based on the sample volume preferred (3 litres or more) for the research on seeds and evertebratae.

**Conclusion**

The strategy here presented for preliminary survey and excavation of palaeo-vegetation in a palaeo-landscape has proven to be efficient and secure. A preliminary survey, preferably by trial trenches, is essential for the planning of the excavation, including aspects such as the number of excavation levels and the employment of manpower and material. The combination of the various protocols for (1) the collection of geomorphological and pedological data, (2) the recording on field drawings and sheets of the wood macrofossils, (3) the sampling of all organic material and (4) the sampling for dendrochronological investigation provided a solid basis for the integral analyses of the data. The recording of the wood macrofossils needs adjustment. The proposed adaptations have not been tested yet. The sampling for the analyses of seeds and insects/mites needed to be extended by sampling also from columns that represent the soil stratigraphy of the site. This method has been used successfully on the second excavation of buried woodlands in Den Haag-Ypenburg. The integrated analyses of the various datasets collected in Zwolle-Stadshagen have led to interesting and surprising conclusions. The results of the research of the disciplines involved are discussed in three successive articles all printed in this issue: “The development of the palaeo-landscape in its hydrological context” by Kooistra, M.J., II; “The reconstruction of the vegetation by means of palynology and wood research” by Kooistra, L.I., et al., III and “The growth pattern and population dynamics of oak and ash” by Sass-Klaassen, U. and Hanraets, E., IV. In the fifth article a synthesis is given of the integrated reconstruction of landscape and woodland in its environmental context by Kooistra, M.J., et al., V.

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References

Andersen, S.Th., 1970. The relative pollen productivity and pollen representation of north European trees, and correction factors for tree pollen spectra. Danmarks Geologiske Undersøgelse Series II, 96: 1-99.

Andersen, S.Th., 1973. The differential pollen productivity of trees. *In*: Birks, H.J.B. & West, R.G. (eds.): Quaternary Plant Ecology. Oxford: 109-115.

Birks, H.J.B., & Gordon, A.D., 1985. Numerical methods in quaternary pollen analysis. London.

Bremt, P. van den, Dirkx, J., During, R., Geel, B. van, Kooistra, L.I., & Tak, G., 1998. Een stekelig beeld van het Atlantische bos. Landschap 15/4: 245-250.

Gaillard, M.-J., Birks, H.J.B., Emanuelsson, U., Karlsson, S., Lagerås, P., Olausson, D., 1994. Application of modern pollen/land-use relationships to the interpretation of pollen diagrams-reconstructions of land-use history in south Sweden 3000-0 BP. Review of Palaeobotany and Palynology 82: 47-73.

Geel, B. van, Buurman, J., & Waterbolk H.T., 1996. Archaeological and paleoecological indications for an abrupt climate change in The Netherlands and evidence for climatological teleconnections around 2650 BP. Journal of Quaternary Science 11: 451-460.

Geel, B. van, Plicht, J. van der, Kilian, M.R., Klaver, E.R., Kouwenberg, J.H.M., Renssen, H., Reynaud-Farrera, I., & Waterbolk, H.T., 1998. The sharp rise of $\Delta^{14}C$ ca. 800 cal BC: possible causes, related climatic teleconnections and the impact on human environments. Radiocarbon 40: 535-550.

Hicks, S., 2001. The use of annual arboreal pollen deposition values for delimiting tree-lines in the landscape and exploring models of pollen dispersal. Review of Palaeobotany and Palynology 117: 1-29.

Jong, J. de, & Zagwijn, W.H., 1983. De vegetatiegeschiedenis van 's Gravenhage en omgeving. *In*: Mulder, E.F.J. de, (ed.), De bodem van 's Gravenhage. Mededelingen Rijks Geologische Dienst 37-1: 44-62.

Kooistra, L.I., Rijn, P. van, Smeerdijk, D.G. van., 2003? Wetland woods of the past: results of the excavation of Zwolle-Stadshagen (The Netherlands), III. Reconstructing the vegetation by means of palynology and wood research. Netherlands Journal of Geosciences, this issue.

Kooistra, M.J., 2003? Wetland woods of the past: results of the excavation of Zwolle-Stadshagen (The Netherlands), II. Development of the palaeo-landscape in its hydrological context. Netherlands Journal of Geosciences, this issue.

Kooistra, M.J ¸ Sass-Klaassen, U., Kooistra, L.I. & Rijn, P. van, 2003? Wetland woods of the past: results of the excavation of Zwolle-Stadshagen (The Netherlands), V.

Synthesis: Integrated reconstruction of landscape and woodland in its environmental context. Netherlands Journal of Geosciences, this issue.

Lageard, J.G.A., Chambers, F.M., & Thomas, P.A., 1995. Recording and Reconstruction of Wood Macrofossils in Three-Dimensions. Journal of Archaeological Science 22: 561-567.

Leuschner, H.-H., Delorme, A., Tüxen, J. and Höfle, H.-C. 1985: Eichenstammlagen in Mooren und Talauen und die Klimaverschlechterung im Subboreal. Flora 177: 283-295.

Leuschner, H.H., Delorme, A., Tüxen, J., Höfle, H.C. 1986. Uber Eichenwaldhorizente in kuestennahen Mooren Ostfreislands [On oak horizons in mires near the coast of Ostfreislands]. Telma 16: 61-82.

Leuschner, H.H., Delorme, A., Höfle, H.C. 1987. Dendrochronological study of oak trunks found in bogs of northwest Germany. *In*: Jacoby, G.C. Jr. and Hornbeck, J.W., (eds.): Proceedings of the International Symposium on Ecological Aspects of Tree-Ring Analysis. U.S. Department of Energy, Publication CONF-8608144: 298-318.

Leuschner, H.H., Sass-Klaassen, U., Jansma, E., Baillie, M.G.L., & Spurk, M., 2002. Subfossil European bog oaks: population dynamics and long-term growth depressions as indicators of changes in the Holocene hydro-regime and climate. The Holocene 12: 695-706.

Munaut, A.V., 1967. Etude paléo-écologique d’un gisement tourbeux situé à Terneuzen (Pays-Bas). Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 17: 7-27.

Munaut, A.V., 1986. Dendrochronology applied to mire environments. Berglund, B.E., (ed.): Handbook of Holocene Palaeoecology and Palaeohydrology. Chichester: 371-385.

Sass-Klaassen, U., Hanraets, E., 2003? Woodlands of the past: results of the excavation of Zwolle-Stadshagen (The Netherlands), IV. Growth patterns and population dynamics of oaks and ashes. Netherlands Journal of Geosciences, this issue.

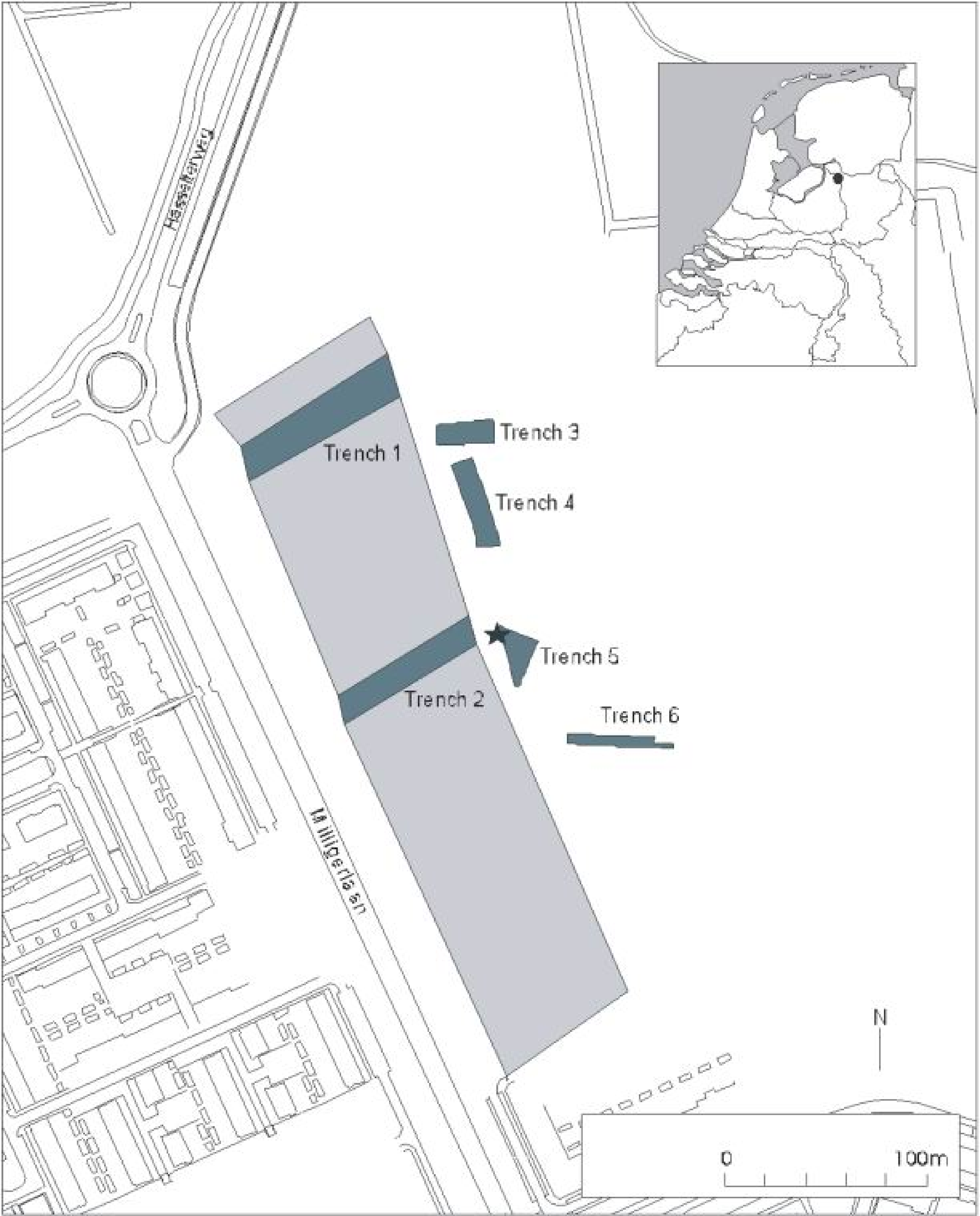
Spurk, M., Leuschner, H.H., Baillie, M.G.L., Briffa, K.R., & Friedrich, M., 2002. Depositional frequency of German subfossil oaks: climatically and non-climatically induced fluctuations in the Holocene. The Holocene 12: 707-715.

Vera, F.W.M., 2002. Grazing Ecology and Forest History. Wallingford.

Vera, F.W.M., 1997. Metaforen voor de wildernis. Eik, hazelaar, rund, paard. ’s Gravenhage.

Zeiler, J.T., & Kooistra, L.I., 1998. Parklandschap of Oerbos? Interpretatie van het prehistorische landschap op basis van dieren- en plantenresten. Lutra 40: 65-76.

**List of figures**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