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SHORT COMMUNICATION

Unlocking the wealth of Dutch pollen data for future research and education

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Abstract
Nearly 100 years ago, scientists started analysing fossil pollen and spores in the Netherlands. Since then, an enormous number of fossil pollen datasets have been generated by several researchers at different research institutes. Until recently, most pollen data from the Netherlands was not publicly available. With this communication we like to advertise that this situation has changed and present progress on the Dutch pollen database project. The data are accessible as part of the European Pollen Database in the NEOTOMA palaeoecological database. Now 600 datasets are available, which include pollen counts from the pioneers of pollen analysis as well as recent studies in the Netherlands. We provide a brief history of pollen analysis in the Netherlands to put the origin of these datasets into perspective. The historical overview does not attempt completeness but highlights the main developments throughout the last 100 years of research.

Keywords History · The Netherlands · Database · Pollen analysis · EPD · Neotoma · Palaeoecology

Open access to Dutch pollen data

Since the start of pollen analysis in the Netherlands, at least 1,500 fossil pollen records are known to have been analysed in the Netherlands. The data have been collected for different projects and stored in different archives, making it hard to access and use them for additional studies. A substantial portion of these data covers sites that are not accessible anymore or no longer exist, making these diagrams highly valuable. A large part of the data has not previously been digitized and is only existing as count sheets. Over the last few years, the need for greater spatial resolution in palynological data has increased. There is also an increasing risk of data being lost, while even old or preliminary studies provide information to motivate new research and provide the only information where sites have been lost. Moreover, pollen data collected since the pioneering phase document the development of the field. The large quantity of Dutch pollen data holds great potential for metanalysis and mapping.

Waldo Zagwijn was one of the first Dutch advocates of publicly sharing data and was striving for ways to implement this. In 1970, he made an inventory of all available Lateglacial diagrams at the Rijks Geologische Dienst (RGD, later the NITG-TNO (Nederlands Instutuut voor Toegepaste Geowetenschappen - Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek) in the Netherlands with the aim of mapping Lateglacial vegetation change. He realized that comparing percentage diagrams from different workers and institutes was challenging, due to differences in taxonomy and pollen sums (see also Janssen 1980). This first national inventory also demonstrated the different areas of activity of the different institutes, with a national coverage of the Geological and Soil Survey institutes (RGD and StiBoKa (Stichting voor Bodemkartering). The regional spread of pollen data was often connected to the location of the different universities, reflecting their research focus and working areas. The focus on sea level studies at the Vrije Universiteit Amsterdam (VU) is a clear example of this, which led to a focus of research in northern and western Netherlands (e.g. Wiggers 1955; Roeleveld 1974), as well as (late) Pleistocene data from the fluvial and coversand area in the Southern and Eastern Netherlands (Kasse et al. 1995; Hoek et al. 2017). At the University of Amsterdam (UvA),

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the main research area was Twente in Eastern Netherlands (e.g. van der Hammen and Wijmstra 1971; Kolstrup 1980; van Geel et al. 1981; Ran 1990). The Radboud University in Nijmegen (RU) focused on the area around Nijmegen, with a link to (archaeological) landscape development (Teunissen 1990) and research at University of Groningen (RUG) mainly focused on the northern part of the Netherlands (Mook-Kamps and Bottema 1987; Mook-Kamps 1995).

The main problem of a centralized database was that it was difficult to store data in a uniform way as there was no digital database structure available yet. A new effort to compile and combine existing datasets in the Netherlands was made in the PhD-project of Wim Hoek under supervision of Waldo Zagwijn and Sjoerd Bohncke. Hoek (1997a, b) compiled and revised more than 250 Lateglacial pollen and early Holocene records, of which most originate from the archives of the StiBoKa and the RGD. For this project he created a relational database in PARADOX following the European Pollen Database structure to gain an improved view on the transition of the vegetation during the Lateglacial to the Holocene in the Netherlands (Hoek 1997b, 2000). In 1992, a Dutch pollen database to store all previously collected pollen data was proposed at a meeting of the Palynologische Kring (Palynologische Kring 1992). Scientists working with pollen data discussed the possibilities and problems of creating and maintaining such a database. However, these discussions and plans were not continued. Another initiative started in 2010 to create an overview of all available pollen datasets from the RGD/ TNO and StiBoKa (Donders et al. 2010). This led to a stratigraphical overview of nearly 1,000 datasets (Gouw-Bouman, unpubl.).

To build on the findings of Hoek (1997a, b) and Gouw-Bouman, we initiated a data collection project focused on digitizing, preserving, and unlocking Dutch pollen data in an online database. The data accessibility project - funded by Utrecht University (UU) - builds on these earlier efforts bringing the collected pollen data into the public domain and digitizing count sheets from important investigations. Rather than creating and maintaining a new database, the project is using the European Pollen Database (EPD, www.europeanpollendatabase.net) within the Neotoma database infrastructure (Williams et al. 2018, www.neotomadb.org). This database is publicly available and can easily be accessed via the website or using Tilia and R. We have reached out to individual researchers, universities, and research institutes an received pollen count data. The majority of the now available data comes from pre-existing data collections such as StiBoKa and RGD/ TNO. Aiming for a preservation of information in old data, we have also digitized count sheets from the archive of Frans Florschütz, the "founding father" of Dutch pollen analysis. With the now available data covering more than 80 years of research it is beneficial to see them in a historical context which we provide below. Here we give an overview of pollen analytical investigations on the environmental history of the Netherlands and do not aim at a comprehensive review of palynological research at Dutch research institutes.

A brief history of pollen based environmental reconstructions in the Netherlands

The study of fossil pollen and spores started in the Netherlands nearly 100 years ago with the work of Frans Florschütz (Hooghiemstra and Richards 2022). In the 100 years, the field has expanded from a mostly stratigraphic geological technique to a multitude of ecological, evolutionary, archaeological, and climatological applications. Palynology developed both in academic and applied laboratories in the Netherlands, yielding several hundreds of pollen diagrams over the past decades providing a detailed account of late Tertiary to Quaternary environmental change.

Onset of pollen analysis in the Netherlands

Frans Florschütz developed pollen analysis in the Netherlands from 1924 onward (Hooghiemstra and Richards 2022). After his bachelor studies in biology, he built a private laboratory in his garden in Velp, in which he started his study of pollen and macrofossils. Commencing in 1925, he and a team of analysts, published more than 100 articles and wrote a similar number of reports on pollen records from the Netherlands (Florschütz 1925). In 1948, Florschütz became professor at Leiden University establishing an academic centre of palynological research at that institute (Fig. 1).

Another important figure in the early development of Dutch palynology was Isaäk Martinus van der Vlerk (1892–1974). He worked together with Florschütz from 1928 to 1958 on the stratigraphy and palaeontology of the Pleistocene in the Netherlands (van der Hammen 1974). In his earlier research, van der Vlerk created a detailed stratigraphical division of the Tertiary in Java and Sumatra (den Tex 1974) based on Foraminifera. In 1928, van der Vlerk obtained a position at the Rijksmuseum van Geologie en Mineralogie in Leiden, where he continued his work on the Tertiary, now focusing on the Netherlands. Together with Florschütz, he investigated a Pleistocene human skull in Hengelo which further sparked his interest in the Dutch Pleistocene (Florschütz and van der Vlerk 1936). While van der Vlerk initially did not work on pollen, he played a significant role in the development of palaeoecological research on the Pleistocene using both macro- and microfossils.

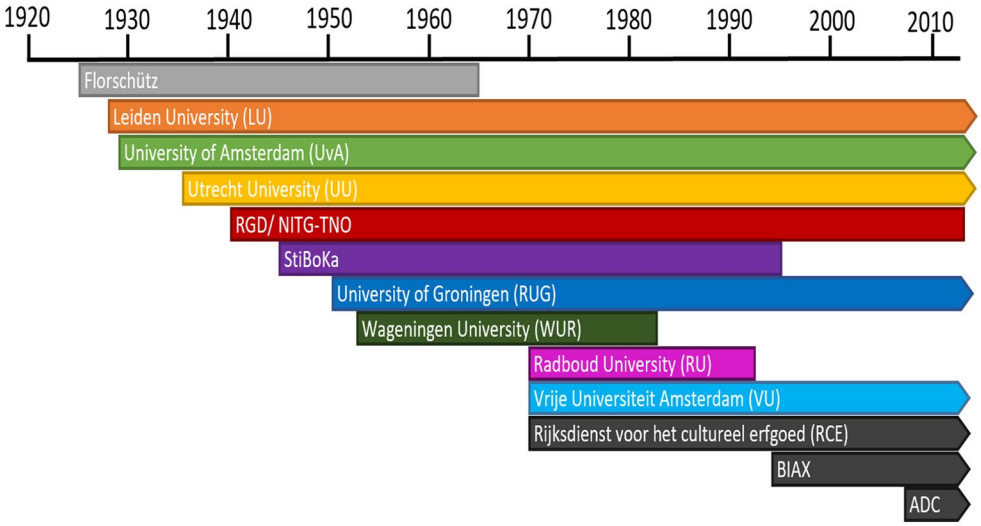

Fig. 1 Overview of research activity in pollen based environmental reconstructions in the Netherlands by research institute. The duration and continuity of different institutes since Florschütz introduced palynology in the Netherlands is shown

Alongside Florschütz, several other researchers started pollen analysis in the Netherlands, one of which was Elisabeth (Betje) Polak (1901–1980). Polak started her studies in biology at the UvA – to this day a prime centre for palaeoecological research, where she analysed peat deposits from the western Netherlands (Havinga and Muller 1981). While her studies were initially mainly focused on macrofossils, she also used pollenanalytical methods, in which she was one of the first in the Netherlands (Havinga and Muller 1981). Before continuing her studies in the Dutch East Indies, she had demonstrated using pollen analysis that *Picea* is not native to the Netherlands while *Pinus* is (Polak 1929). She is most famous for her significant contribution to palynology in both the Netherlands and the East Indies by drawing over 250 different pollen and spore types in high detail, a collection which is currently located at Wageningen University.

Eduard M. van Zinderen Bakker (1907–2002) also started his research on pollen in the Netherlands at the UvA. While van Zinderen Bakker is best known for his studies on the palaeoenvironments of Africa, he started with studies on the ecology of wetland lakes in western Netherlands (van Zinderen Bakker 1942a, b, 1947). During his time in the Netherlands, van Zinderen Bakker educated several students, including Wim van Zeist who became a prominent figure in Dutch palynology (Neumann and Scott 2018). Van Zinderen Bakker moved to South Africa in 1947 to continue his career in tropical palaeoecology. Another important palynologist at the UvA was Thomas van der Hammen (1924–2010), who was an appointed professor in palynology there (Hooghiemstra et al. 2010). Similar to van Zinderen Bakker, he first started his research on pollen analysis in the Netherlands but moved on to work on sites in South America. Here, he became one of the pioneers in tropical palaeoecology.

In 1955, Willem (Wim) van Zeist (1924–2016) finished his PhD in palynological research on the northern Netherlands at Utrecht University (van Zeist 1955). Van Zeist was one of the key researchers at the Biological Archaeological Institute (BAI, later the Groningen Institute of Archaeology, GIA) at RUG, and worked on the link between archaeology and palaeoecology. He started his research in the Netherlands and was one of the first to involve radiocarbon dating in palynological research (van Zeist 1955), but also extended his field of expertise with several studies in the Middle East, Eastern Mediterranean, and northern Africa (Hooghiemstra and Birks 2018). During his time as a professor at the RUG, he supervised several PhD candidates, including Willem (Wil) Casparie and Sytze Bottema, who later continued palynological research at the RUG. Wil Casparie (1930–2009) was an archaeologist at the GIA, and specialist on peat bogs and wood studies (Cappers et al. 2010). Casparie's main focus was on the Netherlands, of which the Roman Velsen and Wijk bij Duurstede (Dorestad) were key sites he worked on. Sytze Bottema (1937–2005) worked as a palynologist at the GIA from 1963 to 2002. From his PhD thesis onward, his main focus was on the eastern Mediterranean and the Near East, where he conducted a great number of studies (Cappers and Woldring 2006). Alongside his studies on the Mediterranean region, Bottema also analysed several pollen diagrams from the northern Netherlands.

While several palynologists changed their focus-point to other regions or tropics, Florschütz and van der Vlerk continued their work in the Netherlands. Alongside the research conducted in his private laboratory, Florschütz worked at several universities throughout his career at which he also trained several students in the analysis of pollen (Hooghiemstra and Richards 2022). Some of his students became heads of research laboratories and in that capacity continued with palynological studies; Frits Jonker (1917–1990) at the

UU, Thomas van der Hammen (1924–2010) at the UvA and Waldo Zagwijn (1928–2018) at the RGD and the VU (Hooghiemstra and Richards 2022).

Rapid developments in Dutch pollen analysis

The academic centres of palynological research in the Netherlands mostly had a supportive function to other research areas, such as archaeology. This led to a different research focus at each university, with archaeology as the main field at the Leiden University (LU) with a group led by Corrie Bakels, and at the RUG with Wim van Zeist, Wil Casparie and Sytze Bottema and most recently a group led by Rene Cappers. Peat palaeoecology and palaeoclimatology both in the Netherlands and in the tropics was developed mostly at the UvA, initially by Thomas van der Hammen. Research on the Netherlands was then continued by Bas van Geel and Jan van Mourik, while research on the tropics was led by Henry Hooghiemstra, and currently by Carina Hoorn, William Gosling and Crystal McMichael. Also at the UvA, palynology was used to aid archaeological research: Willy Groenman-van Waateringe led palynological investigations at the Albert Egges van Griffen Institute (the Institute of Pre- and Protohistorie or IPP), mostly on samples from burial mounds with Jan Peter Pals working on seeds and fruits in these samples. Pleistocene climate stratigraphy has been a focus at the VU, where most of the palynological research was conducted by Piet Cleveringa, who was succeeded by Sjoerd Bohncke, while Thomas van der Hammen, Waldo Zagwijn and Karl-Ernst Behre were successively appointed as extraordinary professor. No longer active are the palynological laboratories at the Wageningen University & Research (WUR) and Radboud University Nijmegen (RU). At the WUR, palynology of soils and pollen preservation was investigated by A.J. Havinga. The RU Nijmegen, a regional centre of palynological study, was initiated by Florschütz and continued by Daan Teunissen until the early 1990's. Here the focus was on vegetation development in the eastern river area. At the UU, the development of landscape ecology, pollen dispersal and pollen morphology were advanced by Roel Janssen and Wim Punt, Hans Joosten, and currently the above authors. The detailed work by Punt furthering the identification of pollen grains culminated in the publication of "The Northwest European Pollen Flora" book series which has become an important aid in the identification of pollen grains in Europe. Graduates of the group conducted their work with a high level of taxonomic precision, like Hanneke Bos (Bos et al. 2006, 2007).

Dutch palynological research also made a major contribution to the systematic study of non-pollen palynomorphs (NPP) and their identification as algae, fungi and other plant and animal remains alongside the analysis of pollen. A classification database was started in 1968 at the Hugo de Vries laboratory (UvA) by Bas van Geel (Miola 2012). In one of his first articles in 1972, he presented the start of this classification system in a study on a core near the German border (van Geel 1972). In this study, he distinguished nearly 50 different NPPs. In the following years, over 1,300 additional NPPs were identified, most described by Bas van Geel and his colleagues (Miola 2012). The most up-to-date overview of all non-pollen palynomorphs can be found at the Non-Pollen Palynomorph Image Database (Shumilovskikh et al. 2022, 2023, http://non-pollen-palynomorphs.uni-goettingen.de).

Initially pollen analysis was widely used for stratigraphy. This was also the initial use of pollen analysis of two major institutes that are the source of most Dutch pollen data: the StiBoKa and the RGD. The StiBoKa was established in 1945 in Bennekom with Cornelis H. Edelman as first director. The institute initially worked on mapping soils, the first two metres of the subsoil, especially focusing on agricultural lands. In the 1950s, they started presenting soil maps of various areas in the Netherlands cumulating in a soil map covering the whole of the Netherlands in 1961 (scale 1:250,000). In the following years, the researchers at the StiBoKa worked on a more detailed soil map at a scale of 1:50,000, of which the first version was completed in 1984 (StiBoKa 1984). To establish the age of the mapped deposits (mostly for organic sediments), pollen analysis already started at the StiBoKa shortly after they were founded in 1947 with a study on the area around Bergen op Zoom (StiBoKa report 49E-BEOM47-1 1947). In the beginning, few samples, often less than five per core, were sent to Florschütz for analysis. The resulting reports only considered a few pollen types, but later studies, led by Karin Koelbloed, became more taxonomically detailed with a higher sample resolution in line with the developments in the field of vegetation history. In 1989, after generating nearly 600 pollen diagrams across the whole of the Netherlands, the StiBoKa was merged with the Institute for Culture technique and water management (Instituut voor Cultuurtechniek en Waterhuishouding, ICW), the Institute for Research of pesticides (Instituut voor Onderzoek van Bestrijdingsmiddelen) and the Landscape department of the Dorschkamp to form the DLO-Staring Centrum in Wageningen. This later fused with the Institute for Forest and Nature research (Instituut voor Bos- en Natuuronderzoek, IBN) to Alterra (Wageningen Environment Research) in 2000. The palynological archive was transferred to the NTIG-TNO and pollen analysis at the former StiBoKa was discontinued.

Alongside the StiBoKa, the RGD began pollen analysis around 1940. The RGD was founded a few years earlier than the StiBoKa in 1918 in Haarlem by the Dutch government with Pieter Tesch (1879–1961) as first director. The

RGD's first main goal was to map the subsurface – especially the location of minerals – across the whole of the Netherlands. The second goal of the RGD was to determine risks of "weak" soil and flooding to improve the Dutch infrastructure (see geologischedienst.nl/over-gdn). The RGD started programs to map the country at a high resolution and incorporated pollen analysis to determine the age of the sediments, similarly to the studies of the StiBoKa. In the first few years from 1935 to 1953, pollen analysis was conducted by Florschütz and his team, like the start of pollen analysis at the StiBoKa (RGD report 1–51 1935–1953). After the "watersnoodramp" in 1953 when large areas of the south-western Netherlands were flooded as a result a large storm and dike breaches, the government asked the RGD to revise the Dutch geological map, which led to a strong increase in pollen research at this institute (Koninklijk Nederlands Geologisch Mijnbouwkundig Genootschap (KNGMG) Bestuur 2018). From 1953 onwards, the RGD (at this point also called the Geologische Stichting) conducted pollen research at their own laboratory first lead by J.W.C. Doppert (RGD report 51 1953) and in 1954, Waldo H. Zagwijn (1924–2018) became the head of the palaeobotanical laboratory of the RGD which he remained until 1992 (KNGMG Bestuur 2018). During the first 15 years of the new laboratory at the RGD, Zagwijn together with Jan de Jong (1928–2020) developed and improved pollen analysis rapidly and from the start integrated the newly available ^{14}C-dating method. Since ^{14}C-dating, an absolute dating technique, was more expensive than relative dating via palynology the latter remained much in use.

Zagwijn was a highly regarded geologist that became one of the most important Quaternary specialists in the Netherlands (KNGMG Bestuur 2018; Hooghiemstra and Hoek 2019). Using palynology as a principal tool, he led many investigations on the age and formation of the sediment cover in the Netherlands (mainly Late Miocene and younger), which led to over one thousand pollen diagrams generated by the RGD during his time as head of the pollen laboratory. His research formed the basis for defining and mapping of the Quaternary sediment deposits in the Netherlands. His work also extended to continental-scale stratigraphy, climate, sea level reconstructions and palaeogeography (Hooghiemstra and Hoek 2019). Jan de Jong started working alongside Zagwijn in 1956 at the pollen laboratory of the RGD. During the 1950 and 1960 s he, together with Zagwijn, worked on many pollen analyses executed at the RGD. Alongside his work at the RGD, he was a part of the establishment of the journal Haarlems Bodem Onderzoek in 1976 that covered all archaeological and palaeoecological research conducted around the city (Palynologische Kring 2021).

In 1997, the RGD was merged with the NITG which was a part of the TNO. The NITG-TNO, now known as TNO-Geological Survey of the Netherlands, continued with pollen research in the Netherlands – led by Frans Bunnik – and is still generating pollen diagrams today. While both the StiBoKa and the RGD analysed an enormous amount of pollen data, most of this data is not publicly accessible and only a selection of sites was published as diagrams in scientific publications (e.g. Zagwijn 1960, 1961, 1963; Jelgersma et al. 1970; Zagwijn and de Jong 1984; de Jong 1991; van Leeuwen et al. 2000; Busschers et al. 2007; Donders et al. 2007; Peeters et al. 2016; Westerhoff et al. 2020). It is important in addition to all the researchers mentioned above to highlight the effort of numerous – mostly female – pollen analysts. While the analysts were mentioned in the original countsheets and often in these institutes' internal databases, they were often not properly credited in older publications. Many of these analysts were extremely skilled and experienced, and likely have analysed most datasets at the RGD and StiBoKa institutes. Also at universities, analysts counting and preparing samples have not always been acknowledged.

With the expanding field of palynology, it became necessary to facilitate the exchange in information and discuss findings. This led to the foundation of the 'Palynologische Kring' (PK) in 1968 as a section of the Royal Netherlands Mining and Geological Society. Since its foundation, the PK has continuously organized symposia, excursions and supported many students through travel grants and, since 2018, the Florschütz-award for best MSc thesis in the field of palynology and palaeoecology. The PK has facilitated the exchange of expertise and support for new generations of scientists, helping to maintain the rich research tradition in palynology of the Netherlands. During meetings of the PK, the creation of a pollen database and thus the collection of data in such a database was discussed as the need arose to preserve Dutch pollen data.

Current pollen analysis and data preservation

With radiocarbon dates becoming more accessible palynology lost its importance as a dating tool, while it remained widely used in palaeoecological reconstructions. Although not all universities and research institutes are still active, six research groups, mostly associated with a university, are still working on pollen analysis (UU, UvA, VU, LU, RUG, and TNO). Over the last 30 years, several commercial research groups with a focus on palaeoecological research have been established in the Netherlands. Pollen analysis is currently frequently used to provide context in archaeological excavations and adding a broader view on the

past landscape. Several commercial agencies carry out palynological research for palaeo-ecological reconstructions (see e.g. www.archeologie.nl and www.biax.nl), and reconstructions in an archaeological context. Also working on pollen analysis in an archaeological context is the Rijksdienst voor het Cultureel Erfgoed (RCE, see www.cultureelerfgoed.nl). The RCE, originally the Rijksdienst voor het Oudheidkundig Bodemonderzoek (ROB), first started pollen analysis in the 1970s. Bas van Geel was appointed here first as palynologist, later Janneke Buurman and currently Otto Brinkkemper.

Since the merger of RGD and NITG-TNO, pollen analysis at the Geological Survey of the Netherlands continued but shifted focus to older deposits, mostly Pliocene and Pleistocene sediments. In addition to their geological research, TNO focusses on bringing scientific content to the public. They build and distribute subsurface models based on core lithology and other proxy data, such as palynology. TNO maintains a data portal (see www.dinoloket.nl) for all users of subsurface information of the Netherlands. However, pollen data are currently not part of this dataset, highlighting the need for a separate initiative to preserve it and make pollen data from the Netherlands available for users.

Data collection and status of the database

Currently, 600 datasets from the Netherlands have been obtained, recovered, digitized, and uploaded to the EPD (Fig. 2). A third of these datasets include dating such as OSL/IRSL or ^{14}C. The large group of undated diagrams mainly dates from the period between 1950 and 1990, when radiocarbon dating was still quite expensive and less commonly used. Diagrams without radiocarbon dating have been dated based on biostratigraphy, and most of them are from the Holocene and the Lateglacial (Fig. 2). About 23% of the currently available datasets document the vegetation during older Quaternary periods and even the late Pliocene. We have also uploaded a few macrofossil diagrams (including plant macrofossils and insect remains), when they were analysed alongside the pollen diagrams on the same core segments, however, this was not the focus on this project. Non-Pollen Palynomorph (NPP) identifications have been uploaded as part of the pollen records.

The minimum meta data requirement for adding datasets were coordinates, which were not always easy to find. Other meta data was added as available, which includes a publication, dating information, lithology, Loss on Ignition (LOI), a site description, among others. Initially, this project focused

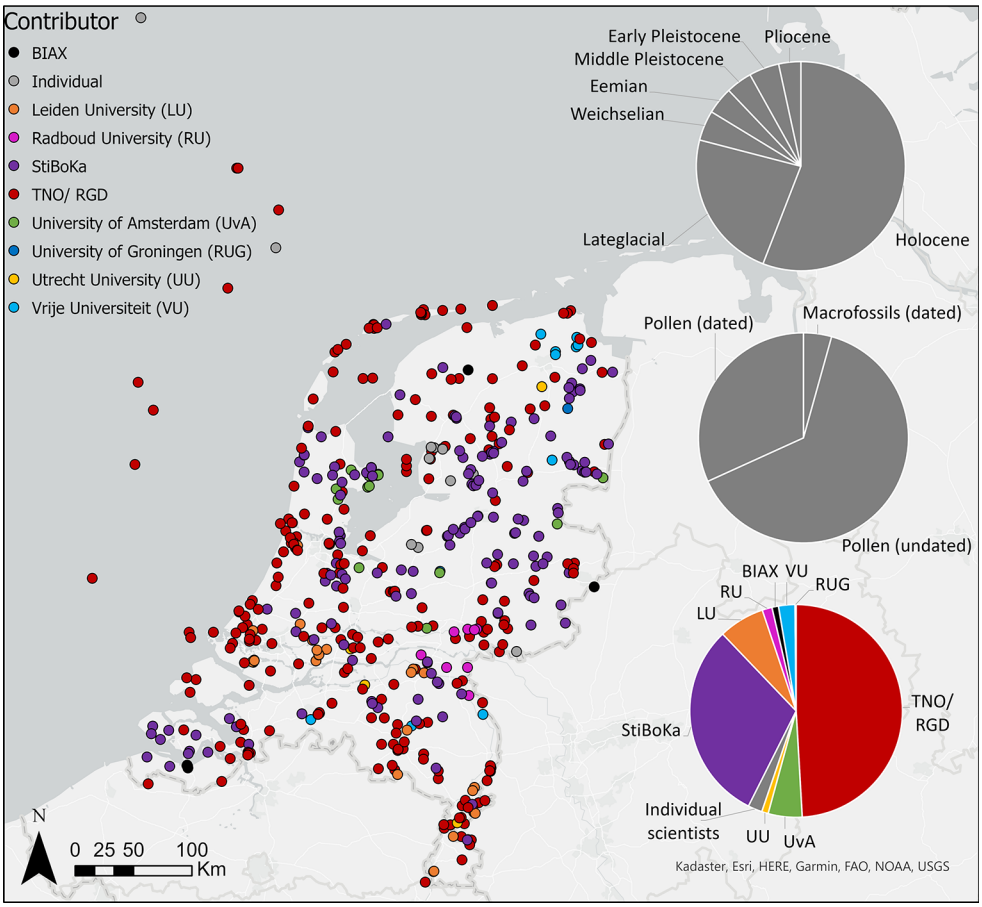

Fig. 2 Current state of available open-source pollen data. With the end of this data mobilization project, 600 datasets have been uploaded to the EPD for the Netherlands. Most data are from the Holocene and Lateglacial and originate from the StiBoKa and RGD. Here, all Dutch sites in the EPD are shown per contributor. Macrofossil data are always linked to a pollen dataset, standalone macrofossils dataset were not included in this project

on published data of which count sheets were available, but unpublished data with clear metadata (i.e. part of a mapping program) were included too. In some cases, only a diagram was available without count sheets, in which case the diagram itself was digitized and added to the database, flagging that the counts or proportions were digitized. For data created before the 1990s digital files were often not available. This meant that the original count sheets, frequently handwritten, were first digitized before uploading the dataset to the database (Fig. 3). Older datasets often contained outdated nomenclature of plant species, genera, or families. Before uploading these datasets, the taxa were harmonized to the most recent nomenclature, while the original name or synonym was saved.

No restrictions were applied to the age of a study to be uploaded as also old investigations yield valuable information that may still be valuable depending on the question. When pollen research started with Frans Florschütz, only ca. 35 pollen taxa were determined per dataset. With the publication of the first edition of the Textbook of Pollen Analysis (Faegri and Iversen 1950) the number of identified pollen grains per dataset increased significantly and continued to rise with further advances in pollen identification during the following decades to c. 100 to 150 pollen taxa per dataset (Fig. 4). From 1970 onwards, no significant difference in the average number of identified pollen taxa was found, implying that, starting in 1970, the continuously expanding knowledge on pollen morphology did not lead to systematic increases in the number of identified taxa. Therefore, datasets from 1970 onwards may be utilized for studies requiring complete taxonomic resolution achieved in standard investigations until the present.

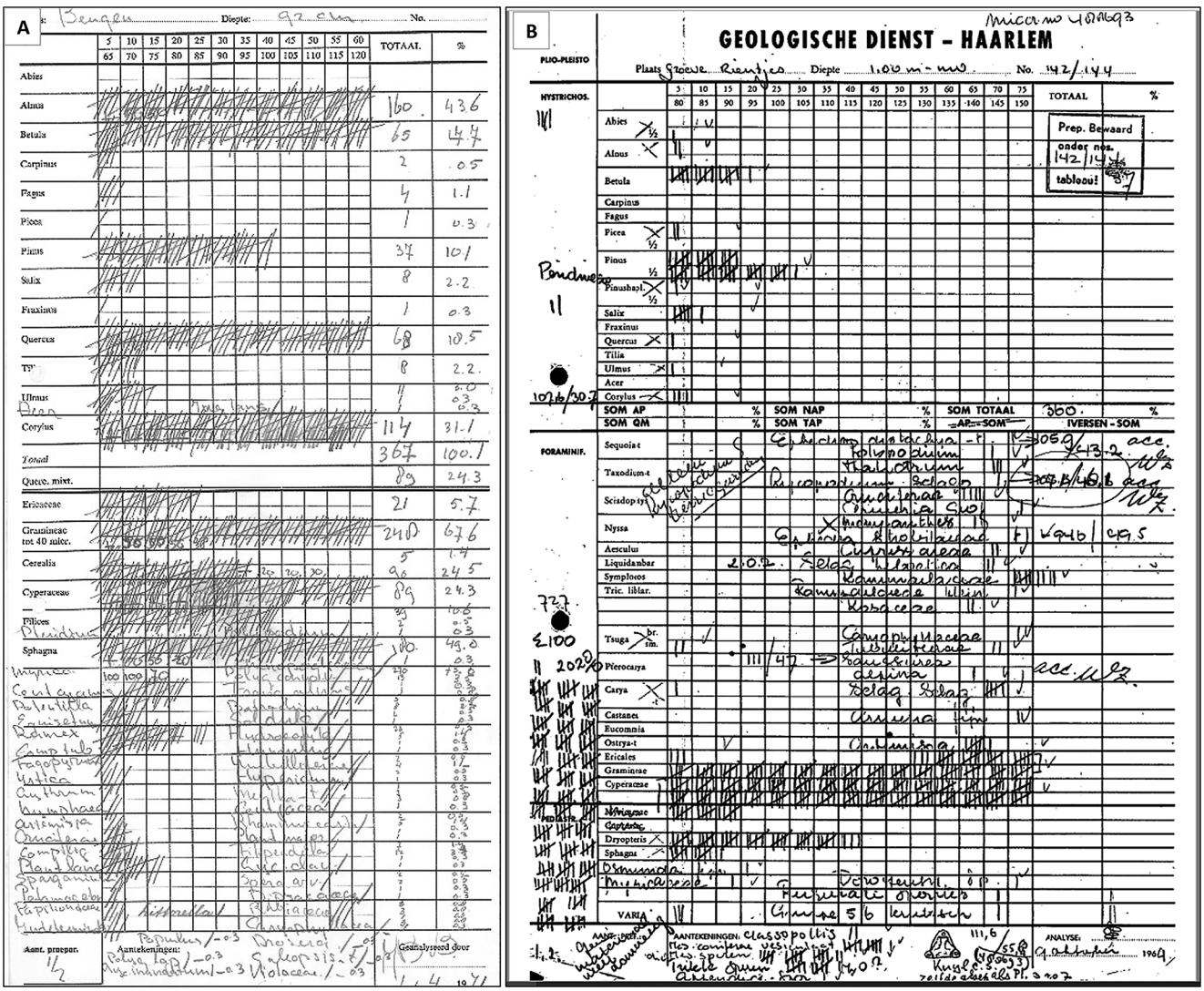

Fig. 3 Example of a count sheet from the Stichting voor Bodemkartering (**A**) and the Rijks Geologische Dienst (**B**). Count sheets were often handwritten and needed to be digitized manually. Frequent problems with manually digitizing count sheets were hard-to-read handwriting and outdated names of plant species, genera, or families

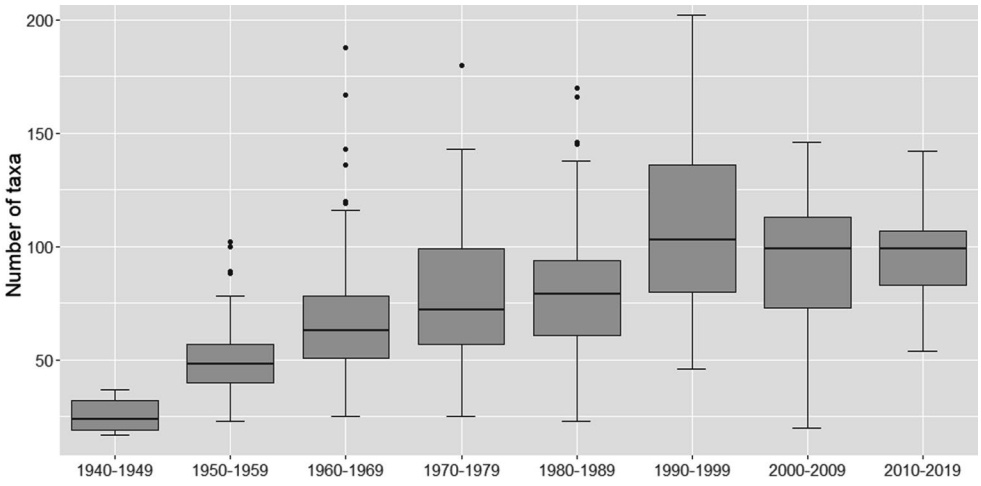

Fig. 4 Number of pollen and NPP taxa per dataset across time. The amount of pollen taxa counted per dataset increased significantly between the 1940s, the 1950s and the 1960s. After that, the amount of counted pollen taxa stabilized. This trend is significant when testing for differences between groups using a one-way ANOVA with a TukeyHSD post-hoc test

This systematic increase in the number of identified pollen types per dataset is one factor that must be considered when selecting data for different analysis. Another constraint may be the depositional environment or the temporal length of the record. While datasets with more samples were prioritized for upload, even sites with few samples, no chronologies and low taxonomic resolution provide valuable information on local site conditions. These sites should still be included in regional synthesis aiming at characterizing the regional heterogeneity in vegetation cover. While the older investigations might not contain a high number of pollen taxa, they do include the larger plant groups and the most commonly occurring tree taxa in the Netherlands. This makes them of great value for studies with nature conservation or reforestation goals. Nevertheless, caution is necessary when using these datasets in a larger analysis as specific indicator taxa may be lacking due to the identification skills at the time rather than their true absence. The UU funded data accessibility project ended in May 2023 and had the main goal to make as many datasets available as possible. Nevertheless, data upload of legacy and new sites will continue albeit at a lower rate. It will also be necessary to review the uploaded data, flag samples with a pollen composition not representing the vegetation of the time of deposition due to redeposition or riverine input. We also aim at reviewing the available chronological information, constructing chronologies for the data where that is lacking and revising chronologies elsewhere. Thus, while there is still a considerable amount of work required to fully utilize the now available data from the Netherlands, we are proud to invite the scientific community to utilize the data. We look forward to interesting projects and publications utilizing this data and ask that this publication should be cited in studies making specific use of the Dutch pollen data.

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References

Bos JAA, Bohncke SJP, Janssen CR (2006) Lake-Level Fluctuations and small-scale vegetation patterns during the late glacial in the Netherlands. J Paleolimnol 35:211–238. https://doi.org/10.1007/s10933-005-8517-0

Bos JAA, van Geel B, van der Plicht J, Bohncke SJP (2007) Preboreal climate oscillations in Europe: wiggle-match dating and synthesis of dutch high-resolution multi-proxy records. Quat Sci Rev 26:1:927–1950. https://doi.org/10.1016/j.quascirev.2006.09.012

Busschers FS, Kasse C, van Balen RT et al (2007) Late pleistocene evolution of the Rhine-Meuse system in the southern North Sea basin: imprints of climate change, sea-level oscillation and glacio-isostacy. Quat Sci Rev 26:3216–3248. https://doi.org/10.1016/j.quascirev.2007.07.013

Cappers RTJ, Woldring H (2006) In memoriam: Professor Sytze Bottema: 6th October 1937–21st November 2005. Veget Hist Archaeobot 15:231–232. https://doi.org/10.1007/s00334-006-0061-y

Cappers RTJ, van Geel B, Groenendijk HA, Streefkerk JG, Stuijts ILM, Vermeeren C, Woldering H (2010) In memoriam Wil Casparie 22 April 1930–7 August 2009: bibliography of W.A. Casparie. Palaeohistoria 51/52(2009/2010):1–7

De Jong J (1991) Pollen-analytical investigation on sediments of pleistocene age at Wageningen (the Netherlands). Meded Rijks Geol Dienst 46:65–70
Den Tex E (1974) Levensbericht van Isaäk Martinus van der Vlerk (31 januari 1892-29 juni 1974). Jaarb KNAW 1974:190–195
Donders TH, Kloosterboer-van Hoeve ML, Westerhoff W, Verreussel RMCH, Lotter AF (2007) Late Neogene continental stages in NW Europe revisited. Earth-Sci Rev 85:161–186. https://doi.org/10.1016/j.earscirev.2007.06.004
Donders TH, Bunnik FPM, Bouman MTIJ (2010) De Nederlandse biostratigrafie database, v1.0 pollen biozones. TNO-rapport TNO-034-UT-2010-01172
Faegri K, Iversen J (1950) Text-Book of Modern Pollen Analysis. Munksgaard, Copenhagen
Florschütz F (1925) A contribution to the knowledge of the pleistocene flora of the Netherlands. Proc Kon Ned Akad Wetensch 28:647
Florschütz F, van der Vlerk IM (1936) The pleistocene human skull from Hengelo. Geological-palaeontological part. Proc Kon Ned Akad Wetensch 39:76–80
Havinga AJ, Muller J (1981) In memoriam Betje Polak (1901–1980), pioneer of peat research in the Netherlands and in the tropics. Acta Bot Neerl 30:337–343
Hoek WZ (1997a) Palaeogeography of lateglacial vegetations: aspects of lateglacial and early Holocene vegetation, abiotic landscape, and climate in the Netherlands. Vrije Universiteit Amsterdam, Amsterdam. PhD thesis
Hoek WZ (1997b) Atlas to Palaeogeography of Lateglacial Vegetations: maps of Lateglacial and Early Holocene landscape and vegetation in the Netherlands, with an extensive review of available palynological data, PhD thesis edn. Vrije Universiteit Amsterdam, Amsterdam
Hoek WZ (2000) Abiotic landscape and vegetation patterns in the Netherlands during the Weichselian Late Glacial. Neth J Geosci 79:497–509. https://doi.org/10.1017/S0016774600021983
Hoek WZ, Lammertsma EI, Bohncke SJP et al (2017) Lateglacial and early Holocene vegetation development and fluvial system changes in the northern Meuse valley, the Netherlands: a review of palynological data. Neth J Geosci 96:93–114. https://doi.org/10.1017/njg.2017.4
Hooghiemstra H, Birks HJB (2018) Rev Palaeobot Palynol 249:87–92. https://doi.org/10.1016/j.revpalbo.2017.10.001. Obituary Willem van Zeist: 12 March 1924-7 October 2016
Hooghiemstra H, Hoek WZ (2019) Waldo Heliodoor Zagwijn (1928–2018): the instigator and architect of european chronostratigraphy. Neth J Geosci 98:e7. https://doi.org/10.1017/njg.2019.9
Hooghiemstra H, Richards K (2022) Frans Florschütz as founding father of pollen analysis in the Netherlands, and expansion of palynology into the tropics. Grana 61:241–255. https://doi.org/10.1080/00173134.2022.2089226
Hooghiemstra H, van Geel B, Cleef AM (2010) Prof. Dr. Thomas van der Hammen (1924–2010). Rev Palaeobot Palynol 162:116–118. https://doi.org/10.1016/j.revpalbo.2010.06.002
Janssen CR (1980) Some remarks on facts and interpretation in quaternary palyno-stratigraphy. Bull Assoc Fr Etude Quat 17:171–176
Jelgersma S, de Jong J, Zagwijn WH, van Regteren Altena JF (1970) The coastal dunes of the western Netherlands; geology, vegetational history and archeology. Meded Rijks Geol Dienst 21:93–167
Kasse K, Vandenberghe J, Bohncke S (1995) Climatic change and fluvial dynamics of the Maas during the late Weichselian and early Holocene. In: Frenzel B, Vandenberghe J, Kasse K, Bohncke S, Gläser B (eds) European river activity and climatic change during the Lateglacial and early Holocene. Paläoklimaforschung 14. Gustav Fischer, Stuttgart, pp 123–150
KNGMG Bestuur (2018) In memoriam: dr. Waldo Heliodoor Zagwijn, paleobotanicus en kwartairgeoloog
Kolstrup E (1980) Climate and stratigraphy in Northwestern Europe between 30,000 B.P. and 13,000 B.P., with special reference to the Netherlands. Meded Rijks Geol Dienst 32:181–253
Miola A (2012) Tools for Non-Pollen Palynomorphs (NPPs) analysis: a list of Quaternary NPP types and reference literature in English language (1972–2011). Rev Palaeobot Palynol 186:142–161
Mook-Kamps E (1995) Palynological investigations of younger Dryas sediments in the northern Netherlands (extended abstract). Neth J Geosci 74:261–264
Mook-Kamps E, Bottema S (1987) Palynological investigations in the northern Netherlands (the Drenthe Plateau). Palaeohistoria 29:169–172
Neumann FH, Scott L (2018) van Zinderen Bakker EM (1907–2002) and the study of african quaternary palaeoenvironments. Quat Int 495:153–168. https://doi.org/10.1016/j.quaint.2018.04.017
Palynologische Kring (2021) In memoriam Jan de Jong (1928–2020)
Palynologische Kring (1992) Meeting notes and agenda
Peeters J, Busschers FS, Stouthamer E et al (2016) Sedimentary architecture and chronostratigraphy of a late quaternary incised-valley fill: a case study of the late Middle and Late Pleistocene Rhine system in the Netherlands. Quat Sci Rev 131:211–236. https://doi.org/10.1016/j.quascirev.2015.10.015
Polak B (1929) Een onderzoek naar de botanische samenstelling van het Hollandsche Veen. University of Amsterdam, Amsterdam. PhD thesis
Ran ETH (1990) Dynamics of vegetation and environment during the Middle Pleniglacial in the Dinkel valley (the Netherlands). Meded Rijks Geol Dienst 44:141–220
Rijks Geologische Dienst, Doppert JWC (1953) Rapport 51. Unpublished
Rijks Geologische Dienst, Florschütz F (1935) Rapport 1. Unpublished
Roeleveld W (1974) The Holocene evolution of the Groningen marine-clay district. Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek 24. Rijksdienst voor het Cultureel Erfgoed, Amersfoort
Shumilovskikh LS, Shumilovskikh ES, Schlütz F, van Geel B (2022) NPP-ID: Non-Pollen Palynomorph Image Database as a research and educational platform. Veget Hist Archaeobot 31:323–328. https://doi.org/10.1007/s00334-021-00849-8
Shumilovskikh LS, Shumilovskikh ES, Schlütz F, van Geel B (2023) Correction: NPP-ID: Non-Pollen Palynomorph Image Database as a research and educational platform. Veget Hist Archaeobot 32:109. https://doi.org/10.1007/s00334-022-00889-8
Stichting voor Bodemkartering (StiBoKa) (1947) Report Bergen op Zoom I (49E-BEOM47-1). Unpublished
Stichting voor Bodemkartering (StiBoKa) (1984) De Bodemkaart van Nederland 1:50000
Teunissen D (1990) Palynologisch onderzoek in het oostelijk rivierengebied: een overzicht. Mededelingen van de afdeling Biogeologie van de Discipline Biologie van de Katholieke Universiteit Nijmegen 16. Radboud Universiteit Nijmegen, Nijmegen
Van der Hammen T (1974) In memoriam Prof. Dr. I.M. van der Vlerk. Neth J Geosci 53:241–243
Van der Hammen T, Wijmstra TA (1971) The Upper Quaternary of the Dinkel valley (Twente, Eastern Overijssel, the Netherlands). Meded Rijks Geol Dienst 22:55–213
Van Geel B (1972) Palynology of a section from the raised peat bog 'Wietmarscher Moor', with special reference to fungal remains. Acta Bot Neerl 21:261–284
Van Geel B, Bohncke SJP, Dee H (1981) A palaeoecological study of an upper Lateglacial and Holocene sequence from 'De Borchert', the Netherlands. Rev Palaeobot Palynol 31:367–448. https://doi.org/10.1016/0034-6667(80)90035-4
Van Leeuwen RJW, Beets DJ, Aleid Bosch JH et al (2000) Stratigraphy and integrated facies analysis of the Saalian and Eemian sediments in the Amsterdam-Terminal borehole, the

Netherlands. Neth J Geosci 79:161–196. https://doi.org/10.1017/S0016774600023647
Van Zeist W (1955) Pollen analytical investigations in the northern Netherlands with special reference to archaeology. Acta Bot Neerl 4:1–81
Van Zinderen Bakker EM (1942a) Successie-onderzoek in het Naardermeer I. De Levende Natuur 47:1–7
Van Zinderen Bakker EM (1942b) Successie-onderzoek in het Naardermeer II. De Levende Natuur 47:25–29
Van Zinderen Bakker EM (1947) De West-Nederlandsche veenplassen. Een geologische historische en biologische landschapsbeschrijving van het water en moerasland. Allert de Lange, Amsterdam
Westerhoff WE, Donders TH, Trabucho Alexandre N, Busschers FS (2020) Early pleistocene Tiglian sites in the Netherlands: a revised view on the significance for quaternary stratigraphy. Quat Sci Rev 242:106417. https://doi.org/10.1016/j.quascirev.2020.106417
Wiggers AJ (1955) De wording van het Noordoostpolder gebied (The genesis of the Noordoostpolder area, The Netherlands). PhD thesis, University of Amsterdam, Amsterdam
Williams JW, Grimm EC, Blois JL et al (2018) The Neotoma Paleoecology Database, a multiproxy, international, community-curated data resource. Quat Res 89:156–177. https://doi.org/10.1017/qua.2017.105
Zagwijn WH (1960) Aspects of the Pliocene and early Pleistocene vegetation in the Netherlands. Meded Geol Stichting series C-III-1-5:1–78
Zagwijn WH (1961) Vegetation, climate and radiocarbon datings in the Late Pleistocene of the Netherlands. I. Eemian and Early Weichselian. Mem Geol Found Netherl, N.S. 14:15–45
Zagwijn WH (1963) Pollen-analytic investigations in the Tiglian of the Netherlands. Meded Geol Stichting Nieuwe Serie 16:49–72
Zagwijn WH, de Jong J (1984) Die Interglaziale von Bavel und Leerdam und ihre stratigraphische Stellung im niederländischen Früh-Pleistozän. Meded Rijks Geol Dienst 37:155–169