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Figure 1 Coring in the Vrouw Vennepolder. (Photograph by Dr. J.A. Mol)

Late Pleistocene/Early Holocene reconstruction of the landscape and the potential for a human presence based on palynological data from Vrouw Vennepolder, Netherlands

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1. Introduction & Background Information

1.1 Introduction

During the summer of 2022 Dr. J.A. Mol led a coring campaign called the Vrouw Vennepolder Project (VVP) in the Vrouw Vennepolder in the municipality of Kaag en Braassem, Netherlands. The goal of this project was to gain a better understanding of the way the landscape had changed throughout the course of the Holocene. During this project samples were taken of the basal peat layer that was located right on top of the Pleistocene sand at around a depth of -12 m NAP. (Mol, 2023) This research is based on these samples.

The main goal is to reconstruct the vegetation of the Vrouw Vennepolder during the Late Pleistocene and Early Holocene in order to help provide a better understanding of what the landscape looked like during this time period. The bigger picture of the region is already known, but hopefully this research can provide a more detailed view of the Vrouw Vennepolder itself. This will be done by studying the pollen from 9 samples taken across the entire basal peat layer and its boundaries into the sand beneath it and the clay above it. The pollen from each sample will be counted using a microscope and then that information will be used to make a pollen diagram which will hopefully allow the local vegetation to be reconstructed.

The second goal is to hopefully narrow down the timeline that these samples represent from just the Late Pleistocene and Early Holocene in general to more specific periods in the Late Pleistocene and Early Holocene. Narrowing down the timeline would be useful because it would add some specificity to the results that would otherwise be very generalized. This will be done in three different ways. First the sediments the samples were taken from will be compared to the known geological events that took place in the western Netherlands at the onset of the Holocene in order to provide a rough timeline. Secondly the biostratigraphy of the local pollen assemblages will be compared to the known biostratigraphy of different time periods in order to provide a more specific timeline. Thirdly the depth of the sampled sequence will be used in correlation with the local sea-level curve in order to provide additional information on a potential timeframe.

The third goal is to investigate the possibility of a human presence in the Vrouw Vennepolder during the Late Pleistocene and Early Holocene. So far there is no conclusive evidence that humans were in the Vrouw Vennepolder during that time but that is largely because the topic hasn't really been studied extensively. (Huizer et al., 2011, p. 14) This will now be done by looking at the potential resources that the Vrouw Vennepolder could have provided to sustain humans, but also the potential ecological challenges that they would have faced. Finally the pollen diagram will also be analyzed in order to see whether it shows indications of human interference with the landscape which can be detected by means of certain indicator taxa.

1.2 Landscape background

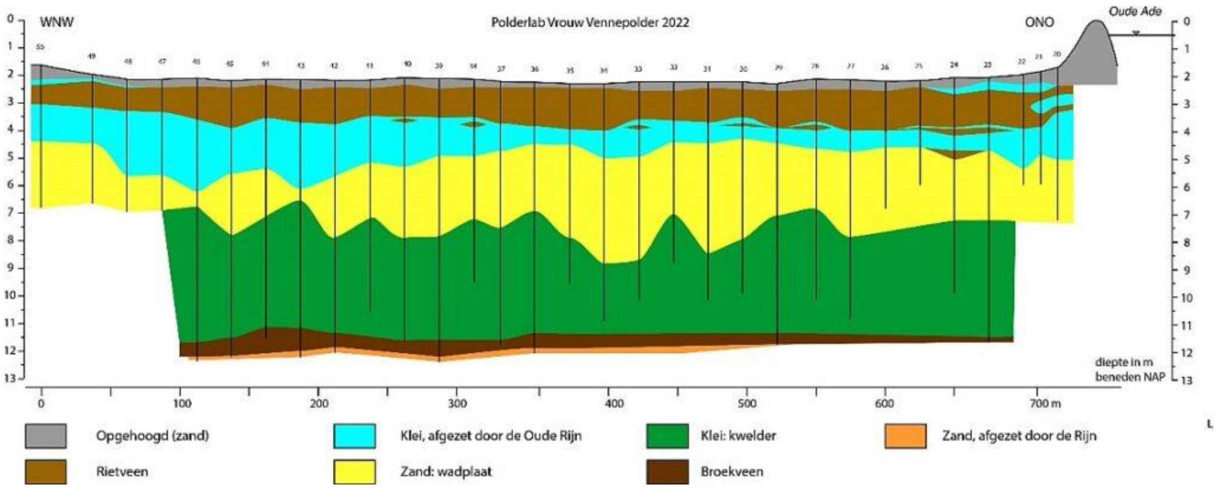

Figure 2 Cross-section of the Vrouw Vennepolder. The numbered vertical lines indicate the corings and the colors indicate the different sediments that were found and their likely origins. (Mol, 2023, Diep bodemonderzoek – Land van Ons)

At the end of the Pleistocene one last ice age took place called the Weichselien. During the Weichselien, land ice expanded southwards from Scandinavia as far down as the northern parts of Germany. This land ice encapsulated a lot of the worlds water causing sea levels to drop astronomically, to the point where the sea-level would have been 110 meters lower than it is today. (Huizer et al., 2011, p. 10) This of course had a massive effect on the Dutch climate of the time which became very continental and took the shape of a tundra landscape. This landscape was dry and cold and featured a very open vegetation that was mainly characterized by herbs and shrubs. These dry and open conditions meant that a strong western orientated wind took control of the landscape and started picking up and depositing fine sand all across the country. (Huizer et al., 2011, p. 10) These sandy depositions are known as cover sands and are part of a layer package called the “Laagpakket van Wierden” which is part of an overarching formation called the “Formatie van Boxtel”. (Huizer et al., 2011, p. 10) What’s interesting is that the Pleistocene sand that was found in the VVP corings (See Figure 2) doesn’t seem to be cover sand but instead seems to be river sand (orange layer in figure 2) that was deposited during the Pleistocene by the Rhine. This interpretation was made based on the rough grainsize of the sand which indicates a fluvial deposition as opposed to the fine grained cover sand that was deposited by the wind. (Mol, 2023)

The Weichselien, and along with it the Pleistocene, came to an end roughly 10.000 BP (present at 1950) when temperatures suddenly started to rise. This rise in temperature thus marked the beginning of the Holocene, the time period we still find ourselves in today. As a result of this temperature increase the water that had previously been encapsulated within the land ice could now return to its liquid form and start filling up the seas again leading to a rapid increase in sea levels. (Huizer et al., 2011, p. 10-11) The temperature also had a great effect on the landscape which instead of a tundra landscape now became a closed birch forest. The rise in sea-level coupled with the cover sand's lack of proper drainage capabilities also caused the groundwater-level to rise leading to a landscape filled with freshwater lakes and swamps which provided the perfect environment for peat to start forming. (Huizer et al., 2011, p. 10-11) This layer of peat is known as the "Basisveen Laag" (dark brown layer in figure 2) and it belongs to the formation called the "Formatie van Nieuwkoop". (Huizer et al., 2011, p. 10-11) This layer is nowadays merely around half a meter thick whereas it used to be much thicker. This is due to the fact that peat is easily compressed by the heavy deposits located on top of it. This compression causes great problems when trying to assign dates to it and the superimposed layers using depth measurements. (Huizer et al., 2011, p. 10-11)

As time goes by the rate at which the sea-level is rising starts to slow down giving sea currents and waves the opportunity to start forming the coastline that we still have today. (Huizer et al., 2011, p. 11) As a result at around 8000 BP (Mol, 2023) the sea gains a more prominent role in the municipality of Kaag en Braassem and starts flooding it more often. This forces the freshwater lakes and swamps eastwards further inland and fills the municipality with tidal deposits made up of fine clay and sand. These layers of clay and sand are assigned to the "Laagpakket van Wormer" which in turn belongs to the "Formatie van Naaldwijk". (Huizer et al., 2011, p. 10-11) This increasing influence of the sea is also clearly visible when looking at figure 2. At first the sea only floods the area regularly and so you get a salt marsh (green layer in figure 2) that is defined by deposits made up mainly of clay with some sand layers mixed in. However as the sea starts flooding the area more frequently you end up with a mudflat (yellow layer in figure 2) which is defined by deposits made up mainly of sand with some clay layers mixed in. (Mol, 2023)

Around 6400 BP the municipality became susceptible to a new influence in the form of the Old Rhine. This river went on to deposit sand and clay in parts of the municipality and these deposits belong to the "Formatie van Echteld" (blue layer in figure 2). (Huizer et al., 2011, p. 11)

The beach ridges on the coast continued to develop causing the coast to expand outwards towards the sea causing the sea to became less of an influence on the municipality. The protection now provided by the beach ridges meant that lagunes started to form in the municipality. It also caused the groundwater-level to rise which in time turned the salty lagunes fresh and in doing so created the perfect environment for peat to start forming again at around 5000 BP. (Huizer et al., 2011, p. 11; Mol, 2023) This peat layer (light brown layer in figure 2) is classified under the “Hollandveen Laagpakket” which in turn belongs to the “Formatie van Nieuwkoop”. (Huizer et al., 2011, p. 11) This peat layer has also shrunk immensely in size but not due to the weight of overlying deposits like the “basisveen”. Instead it is the result of farmers artificially lowering the groundwater-level in order to be able to use the plots of land for their cattle. This practice drains the water from the peat causing it to subside which is the reason why the ground level nowadays lies at around two meters below sea-level. (Mol, 2023)

In recent years farmers have added a final artificial layer (grey layer in figure 2) to the sequence that is made up of manure and material that has been dredged from the nearby creeks, rivers and lakes in order to fertilize the nutrient deficient fields. (Mol, 2023)

1.3 Flora background

The Lower Rhine Basin was home to a large range of flora throughout the Late Pleistocene to Early Holocene. The exact composition of course varied a lot throughout the Basin depending on local conditions, but there are still some larger patterns that emerged. (Brouwer, 2011, p. 148)

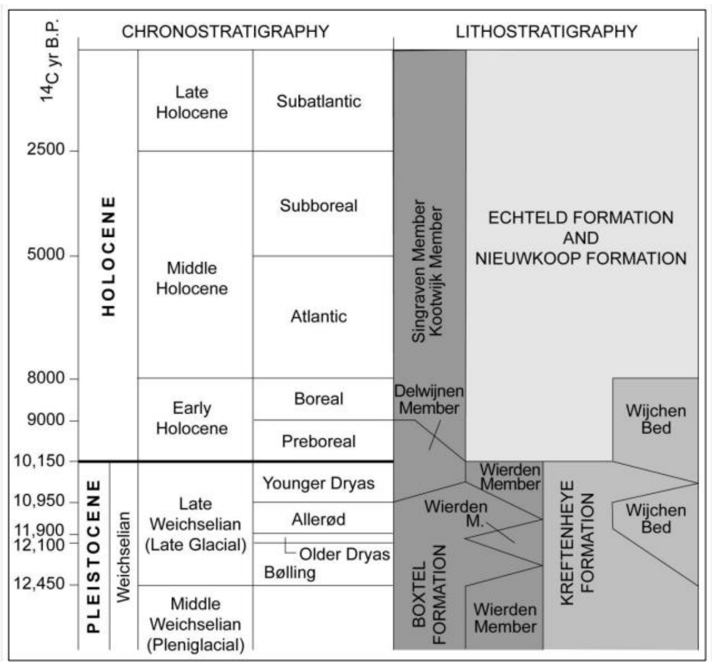

Figure 3 Chronostratigraphy and lithostratigraphy of the Rhine-Meuse delta. (Brouwer, 2011, p. 136)

The Weichselien (See Figure 3) was characterized by cold periods and warmer periods that alternated each other. The Bølling period was one of the warmer periods and was characterized by temperate park landscapes with occasional trees and *Betula* forests. These environments were mainly home to *Betula* trees, *Pinus*, *Salvia* and *Artemisia*. Folowing this warmer period was a cold period called the Older Dryas which was characterized by subarctic park landscapes. (Brouwer, 2011, p. 149) A warmer period then followed in the form of the Allerød which saw the return of the *Betula* forests only this time with a higher number of *Pinus* trees than before. The Weichselien then came to an end with the cold period of the Younger Dryas which brought back the subarctic park landscape that had been present during the Older Dryas. (Brouwer, 2011, p. 149) The vegetation would have mainly consisted of *Poaceae*, grass-like flora, shrubs and herbs, including species like *Artemisia campestris* and *Sanguisorba minor*. (Weeda & Deursen, 1994, p. 50-51)

The onset of the Holocene brought along the Preboreal period which was characterized by more mixed and closed woodland. The two mainstays were still *Betula* and *Pinus*, but *Populus* trees were also abundant in these forests and so were *Corylus*, *Quercus*, *Ribes nigrum*, *Humulus lupulus* (*Cannabinaceae*) and many other shrubs and herbs. *Poaceae* grasses however saw a sharp decline. (Brouwer, 2011, p. 149-150) The moist soils near water were home to *Salix* shrubs and *Poaceae* reed swamps that accommodated flora like *Urticaceae*, *Cyperaceae*, *Filipendula ulmaria* and *Thalictrum*. The wetlands were home to many submerged aquatic flora such as Algae and also floating ones like *Nymphaeceae* and *Potamogeton*. (Brouwer, 2011, p. 149-150)

Then came the Boreal period which was characterized by an increasing density in its forests. *Pinus* was still a mainstay in these forests along with ferns now, however *Betula* had started to decline. Initially during this period *Corylus* rose to a very prominent position but it quickly tapered off again. (Brouwer, 2011, p. 150) *Quercus*, *Ulmus* and *Tilia* were also increasing in significance. The *Salix* shrubs that had grown near water were now partially being replaced by *Alnus* and many other flora like *Poaceae* grasses, *Cyperaceae* and marsh herbs were also growing in these areas. Peat formation started in the west of the Basin and the aquatic flora from the Preboreal hadn't changed. (Brouwer, 2011, p. 150)

During the Atlantic period the composition of the forest changed dramatically. *Quercus* had become the main component of the forest with some input from *Ulmus*, *Fraxinus* and *Tilia*. Whereas *Betula*, *Pinus* and *Corylus* had all significantly declined with only *Corylus* occasionally peaking slightly in its numbers. The forest ground was now mainly covered by *Viscum*, *Ilex* and *Hedera*. (Brouwer, 2011, p. 150-151) The moist soils of river dunes were home to *Urticaceae*, whereas the shallow wet soils near water were home to *Poaceae* reeds and *Cyperaceae*. *Alnus* continued to replace *Salix* in the marsh woodlands with the ground here being home to flora like *Celastraceae*, *Mentha*, *Humulus lupulus* (*Cannabinaceae*) and *Lythrum*. In between these *Alnus* marshes and the peat bogs, *Thelypteris palustris* made its home alongside semi-aquatics like *Typha*, *Alisma* and *Juncaginaceae*. The slow open water is where Algae and aquatics like *Potamogeton* and *Nymphaeceae* made their home. (Brouwer, 2011, p. 150-151)

1.4 Archaeological background

Figure 4 Map of the Benelux showing the distribution of Upper Paleolithic and Early Mesolithic people. The Upper Paleolithic people consist of the Magdalenian (1), Hamburgian (2), Ahrensburgian (3) and Federmesser (essentially the whole region). Early Mesolithic sites also occurred throughout the entire region. (De Bie & Vermeersch, 1998, p. 30, DOI: 10.1016/S1040-6182(97)00052-9)

During the Weichselien many different groups of Late Paleolithic hunter-gatherers visited the general Benelux region (See Figure 4). In general they seem to have spread out during the warmer periods like the Bølling and the Allerød and then subsequently retreated back during the cold Older Dryas and

Younger Dryas. (De Bie & Vermeersch, 1998, p. 30) Magdalenian groups started making short temporary visits to the southern part of the Benelux at the onset of the Bølling. Possibly at the same time or maybe slightly later Hamburgian groups started occupying the northern part of the Benelux. There is also a possibility that Creswellian groups visited the Benelux during this time but that is as of yet unproven. (De Bie & Vermeersch, 1998, p. 39) After the Older Dryas, the beginning of the Allerød heralded the arrival of Federmesser groups who managed to occupy the entire Benelux but probably didn't manage to remain on into the Younger Dryas. The Younger Dryas saw the entire Benelux unoccupied be it for a small presence of Ahrensburgian groups in the east. (De Bie & Vermeersch, 1998, p. 39) In general these groups of hunter-gatherers travelled around in small groups using small temporary camps and hunted various types of large mammals. During the cold Older Dryas and Younger Dryas they would have focused on animals like reindeer, horses and mammoths, whereas aurochs and wild boar would have been mainstays during the warmer Bølling and Allerød periods. (Rappol & Soonius, 1994, p. 18)

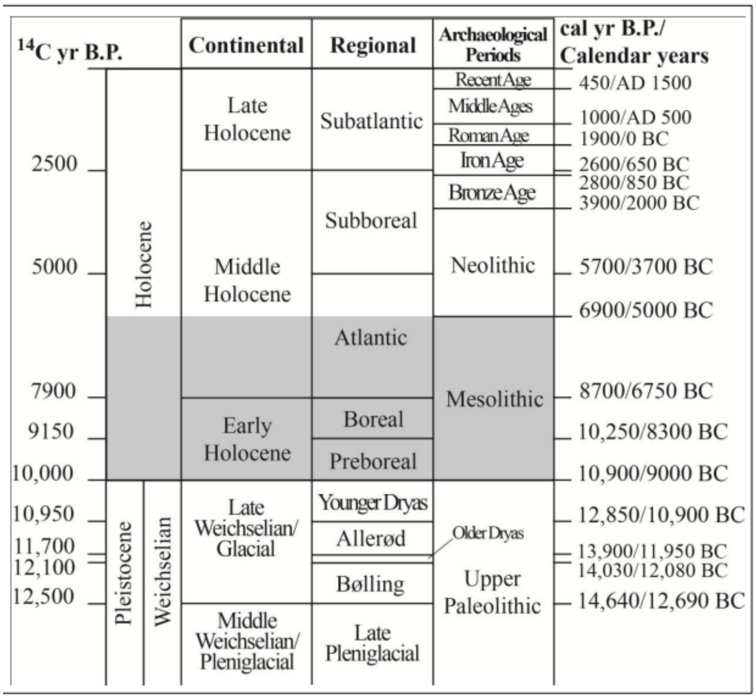

Figure 5 Timeline of Geological and Archaeological periods. (Brouwer, 2011, p. 58)

The Early Mesolithic groups (See Figure 5) that arrived in the Benelux roughly around the beginning of the Holocene seem to have connections to both Ahrensburgian and Federmesser groups. After a while they managed to occupy the entire Benelux and from then on the region has been permanently occupied. (De Bie & Vermeersch, 1998, p. 39) The difference between these Early Mesolithic groups and the preceding Late Paleolithic groups is small and mainly hinges on the change in climate and landscape that was brought on by the Holocene. (Brouwer, 2011, p. 60-61) The changing conditions of course meant that the faunal composition changed greatly in the region which in term effected the subsistence strategies of Early Mesolithic groups. The numbers of large steppe animals either decreased rapidly like horse and most bovids or they just vanished completely over time like reindeer and mammoths. It wasn't long before the large animals that were being hunted instead consisted of roe deer, red deer and wild boar. (De Bie & Vermeersch, 1998, p. 30) Although hunting these large animals was still the main dietary focus, they were now starting to diversify their diets compared to Paleolithic hunters-gatherers. Birds, fish and many different kinds of plant products were now for instance important food sources. *Corylus* nuts were even heated using coals before they were eaten. (Brouwer, 2011, p. 68-69) This diversification was of course a result of the landscape changing and now being home to smaller animals that operated in smaller and more specific territories. (Rappol & Soonius, 1994, p. 20) This caused the hunter-gatherers to themselves occupy smaller territories and instead move their small settlements around more often within the region in order to be able to access these different resources. (Brouwer, 2011, p. 67)

The beginning of the Late Mesolithic coincided with the beginning of the Atlantic period and this presented new problems for the Mesolithic people. The forests became more dense making them harder to traverse, many inland lakes got clogged with organics making them unsuitable as sources of drinking water and a lot of low lying land got drowned by water therefore reducing the amount of available land. These new wetlands however also provided many useful resources. In general the vegetation was also more stable and diverse which meant that it was easier to predict when and where certain resources could be attained. (Brouwer, 2011, p. 72-73) These changes once again caused people to adapt. Larger sites appeared that were occupied for longer times in combination with many smaller sites located near specific resources. It appears the larger sites were almost like home bases where people stayed maybe even year round and from which they then made trips to acquire specific resources, whereas the smaller sites were likely seasonal settlements where people stayed during a season in order to gather a specific resource. (Brouwer, 2011, p. 76-77) In spring for instance rivers provided plenty of fish, whereas in summer coastal areas provided a wide range of food. Autumn on the other hand provided the availability of many fruits and nuts, whereas winter mainly had small animals to offer. (Rappol & Soonius, 1994, p. 20) Interestingly compared to the earlier periods there was also a massive increase in the amount of settlements on the coast and a massive reduction in the amount of settlements further inland, which is probably related to the lakes getting clogged and the forests becoming harder to traverse. The diets of Late Mesolithic groups were largely the same as the ones of Early Mesolithic groups except for a slightly more prominent position for plants and a much bigger reliance on marine resources, shellfish in particular being important. (Brouwer, 2011, p. 78-79)

2. Strategy & Methodology

2.1 Sampling strategy & methodology

Figure 6 Image of the Vrouw Vennepolder. The numbered dots indicate the corings and coring 51 is where the samples used in this research were taken from. (Figure by Dr. J.A. Mol)

During the Vrouw Vennepolder Project samples were taken from two different corings. These two corings were chosen to be sampled because they contained a thick “Basisveen” layer that was relatively easy to access. The first coring that was sampled was coring 51 which was located right next to coring 45 (See Figure 6) and was done solely for the purpose of retrieving uncontaminated samples. Its ground level coordinates were X: 97724,065; Y: 467502,659; Z:-2.195 m NAP. The second coring that was sampled was coring 62 which had the ground level coordinates X: 97722,123; Y: 467502,522; Z: -2.184 m NAP. The research done in this paper is based solely on the samples taken from coring 51 which were sampled in a lab from the whole core.

In order to get the samples from coring 51 the corer was first brought down to the depth at which the “Basisveen” layer was expected to start based on the information from coring 45. The goal was to be able to get the entire peat layer including its transitions into the upper clay layer and the lower sand layer in one gauge in order to have an entire undisturbed sequence. This proved impossible however given the great depth at which the peat was located because the gauge kept filling up with excess material from higher levels. The sequence was therefore sampled across three different gauges. The first gauge covered a depth of 900-930 cm below ground level, the second gauge covered a depth of 885-985 cm below ground level and the third and final gauge covered a depth of 970-987 cm below ground level. Seen as the depth of the first gauge was completely covered by the second gauge, only the second and third gauges were used for this research.

2.2 Pollen preparation strategy & methodology

Figure 7 Gauge containing the upper section of the sequence. This gauge contains clay sediments and peat sediments. (Photograph by A. Lynch)

Figure 8 Gauge containing the lower section of the sequence. This gauge contains peat sediments and sand sediments. (Photograph by A. Lynch)

The sequence (See Figures 7 & 8) consisted mainly of peat with clay being positioned above it and sand being positioned below it. 1 cm thick samples were taken directly above and below both the clay-peat boundary and the peat-sand boundary with the rest of the samples being spaced out evenly at an interval of roughly 10 cm throughout the peat. The samples were made only 1 cm thick in order to have a better resolution and to avoid the risk of missing any changes in the sequence. Using a scalpel the contaminated outer layer was then scraped from the gauge and around 2 cm3 worth of material from each sampling location was transferred to test tubes with distilled water. 2 cm3 were taken from each location in order to make sure that there would also be enough pollen to observe in the sand samples which usually tend to have fewer pollen in them. Two lycopodium tablets were then added to each test tube after which the tubes were shaken in order for the tablets to dissolve. Each lycopodium tablet contains 9666 chemically altered lycopodium spores and they are added to the test tube in order to provide a way of calculating the pollen concentration of the sampled material. In the end there were 9 samples with sample 1 being the deepest sample from the sand and sample 9 being the shallowest sample from the clay. In relation to the ground level their depths are as follows: 1 = 984.5 cm, 2 = 983.5 cm, 3 = 969.5 cm, 4 = 959.5 cm, 5 = 950.5 cm, 6 = 940.5 cm, 7 = 930.5 cm, 8 = 920.5 cm and 9 = 919.5 cm.

The test tubes were then put in a centrifuge at 3600 rpm for 3 minutes in order to separate the pellet from the supernatant. Once that was done as much of the supernatant as possible was poured out without disturbing the pellet and then the tubes were vortex mixed in order to shake loose the pellet.

Tetra sodium pyrophosphate mixed with demineralized water at 0,1 Molar was added in order to disaggregate the mixture by dissolving the electric bonds in clay. In order to help stimulate this reaction the test tubes were put in a heating block set to 90°C for 10 minutes while occasionally being stirred with magnetic stirrers. Once the ten minutes were over demineralized water was added to the test tubes and they were then put back in the centrifuge at 3600 rpm for 3 minutes. The supernatant was then poured out, demineralized water was added and the tubes were mixed using the vortex mixer in order to shake loose the pellet and remove any residue chemicals. They were then once again put back in the centrifuge at 3600 rpm for 3 minutes and the supernatant was poured out. Potassium hydroxide mixed with demineralized water at 10% w/v was added in order to dissolve the humic acids in the mixture. The tubes were then once again put in a heating block at 90°C this time for 20 minutes.

They were then mixed using the vortex mixer before being sieved through sieves of 200 micron into conical flasks. Whatever made it through the sieve was then poured back into the test tubes. Given that a lot of demineralized water was used to force the mixture through the sieve and to get the mixture from the conical flasks back into the test tubes, the mixture didn't fit in the tubes anymore and therefore it had to be transferred across in multiple goes. After the tubes had been filled they went in the centrifuge for 3 minutes at 3600 rpm and then the supernatant was poured out in order to make room for the rest of the mixture to be transferred over from the conical flasks. The tubes were then topped off with demineralized water and put back in the centrifuge at 3600 rpm for 3 minutes after which the supernatant was poured out again. The process of adding demineralized water, vortex mixing, centrifuging at 3600 rpm for 3 minutes and pouring out the supernatant was then repeated two more times. For the tubes containing samples 1 and 2 a little hydrochloric acid was added in order to remove the calcium carbonate that was present in these samples due to their sandy nature. Tubes 1 and 2 were topped off with demineralized water, centrifuged at 3600 rpm for 3 minutes and then the supernatant was poured out. All the samples were then vortex mixed before being transferred to smaller 12 ml test tubes with rounded ends. They were then topped off with water, centrifuged for 3 minutes at 3600 rpm and their supernatant was poured out. For sample 8 the process had to be repeated a second time in order to fit everything in the smaller test tube.

The small tubes were then topped off with glacial acetic acid in order to remove all the water from the mixture. The process of adding glacial acetic acid, vortex mixing, centrifuging at 3600 rpm for 3 minutes, pouring out the supernatant and vortex mixing again was repeated two times. The tubes were then filled halfway with acetolysis which consists of 10% sulfuric acid and 90% acetic anhydride in order to break down the organic material in the sample. The tubes were then put in a heating block at 90°C for 3 minutes while being continuously stirred. Once they were removed from the heating block they were topped off with glacial acetic acid in order to stop the reaction. The process of filling the tubes with glacial acetic acid, vortex mixing, centrifuging at 3600 rpm for 3 minutes, pouring out the supernatant and vortex mixing again was carried out two times. The process of filling the tubes with demineralized water, vortex mixing, centrifuging at 3600 rpm for 3 minutes and pouring out the supernatant was then repeated four times.

Sodium polytungstate mixed with demineralized water was then added which has a very high density of 1,8 gram/ml which is higher than the density of the organics in the samples. This means that after the sodium polytungstate has been added to the tubes, the tubes have been vortex mixed and then have been in the centrifuge at 2000 rpm for 20 minutes the organics actually float to the top because they have a lower density than the surrounding liquid. New test tubes were filled with 5 ml of water and the organics from the old tubes were transferred to the new ones using a transfer pipet. The new tubes were topped off with demineralized water, vortex mixed and put in a centrifuge at 3600 rpm for 3 minutes after which the organics had once again gathered in the bottom which meant the supernatant could be poured out again. Meanwhile the old tubes were filled with sodium polytungstate again and put in the centrifuge at 2000 rpm for 20 minutes in order to be able to transfer the remaining organics from the old tubes to the new ones. After all the organics had been transferred into the new tubes, the new tubes went through the process of being filled with demineralized water, vortex mixed, centrifuged at 3600 rpm for 3 minutes and the supernatant being poured out four separate times.

A little ethanol was then added to even smaller 1,5 ml pointed tubes. The pellet was then transferred to these smaller pointed tubes using a transfer pipet and the tubes were then topped off with ethanol in order to remove the water from the samples. These pointed tubes were then vortex mixed, mini centrifuged at 2500 rpm for 2 minutes and the supernatant was then poured out again. Remaining pellet from the bigger tubes was then transferred over to the pointed tubes, ethanol was added and the same process from before was repeated again. In order to get the very last bits of pellet from the large tubes, isopropyl alcohol (IPA) was added to them and then the remainder of the pellet was transferred to the smaller pointed tubes. These pointed tubes were then topped off with IPA in order to remove any remaining water. They were subsequently vortex mixed, mini centrifuged at 2500 rpm for 2 minutes and then the supernatant was removed using a pipet. Tubes 1, 2, 5 and 5B still contained too much water or IPA and so they were filled up with IPA and put through the same process again. Once all the samples were done, silicon oil with a viscosity of 10.000 CST was added to the tubes and they were then stirred in order to remove the IPA. They were then put in a heating block at 40°C for half a day with some occasional stirring.

The samples were then ready to be smeared in between two thin pieces of glass in order to examine the pollen under a microscope.

2.3 Research strategy & methodology

There were three students working on the nine samples, so each did three samples. The preparations were looked at under a microscope and all the pollen and spores were counted until ideally at least 200 land pollen were counted in order to get a good enough representation of the pollen and spores that were present. Due to time constraints and the poor preservation of some of the samples not every sample ended up with 200 land pollen, but each sample at least had enough pollen in order to get a relatively accurate view of the situation. Once all the samples had been studied under the microscope, all the data from the different samples was then combined into a table. This table shows the absolute numbers that were counted for each taxa in every separate sample and is therefore very useful in regards to showing the raw data that was acquired. All the numbers of the counted pollen and spores were then also converted into percentages of the total amount of land pollen present in each individual sample using the computer program Tilia. This produced a second table were the data is presented in percentages instead of absolute amounts. This table is also very useful because it allows for more accurate comparisons between the pollen assemblages of different samples. This is the case because all the samples had different totals of counted land pollen meaning that comparing the absolute numbers between different samples can provide an inaccurate picture of the situation. By presenting the counted pollen numbers in percentages of their own individual totals this problem is avoided. The percentages table was then converted into two pollen diagrams using Tilia again. One diagram showing all the land pollen and one diagram showing the other pollen and spores that were present in the samples. These pollen diagrams are a convenient way to display the local pollen assemblages of the different samples and they provide the opportunity to identify local pollen assemblage zones (LPAZ) across multiple samples.

The pollen diagrams will thus be used to identify the different LPAZs that are present within the data in order to reconstruct the landscape of the Vrouw Vennepolder during the Late Pleistocene and Early Holocene. This broad timeframe will also be narrowed down by comparing the sampled sediments to the known geological events of the time in the western Netherlands and by comparing the biostratigraphy of the LPAZs to the known biostratigraphy of different time periods of the Pleistocene-Holocene transition in the Netherlands. Furthermore the depths of the sediments will also be correlated with the local sea-level curve in order to provide additional information on a potential timeframe. The possibility of a human presence in the Vrouw Vennepolder during this time will also be investigated by looking at the potential resources that the Vrouw Vennepolder would have had to offer and the ecological challenges that it would have provided for potential occupants. Finally the pollen diagrams will also be analyzed for potential indications of human interference as shown by so called indicator taxa.

3. Results

The results consist of two tables and two pollen diagrams. The first table (See Table 1) shows the absolute amounts of pollen that were counted for all taxa at the nine different sampling depths. The sampling depths are shown in cm below ground level and can be seen at the top of the table. The second table (See Table 2) displays the same data only now in percentages of the total land pollen count which can be seen at the very bottom of the table and is made up of the pollen from all trees, shrubs, herbs and climbers. The first pollen diagram (See Figure 9) displays the pollen from the groups that make up the total land pollen count, being of course once again trees, shrubs, herbs and climbers. The depths are once again displayed in cm below ground level and there is a lithology section that shows the sediment types belonging to the different depths. There is also a section showing how the total land pollen is divided among the four different groups throughout different depths in order to provide a clear picture of how the composition changed throughout time. There is also a final section that displays how similar the different sampled sections are to each other in order to be able to construct different LPAZs. Based on the data there appear to be two distinct zones which are identified as LPAZ VVP-1 and LPAZ VVP-2. It is possible that LPAZ VVP-1 actually represents two different zones but in order to determine this the depths below it would have had to been sampled which is not the case here, so it will be treated as one zone. The second pollen diagram (See Figure 10) displays the same information only for the remaining groups of pollen and spores which include groups like aquatics, algae and ferns.

Table 1 Counted VVP pollen in absolute numbers. (Table by Dr. I.M. Kamerling & A. Lynch)

Taxa	Group	919,5	920,5	930,5	940,5	950,5	959,5	969,5	983,5	984,5
Picea	Trees	0	1	0	0	0	0	0	0	0
Pinus	Trees	8,5	4	7,5	2,5	8	4,5	14	84	78,5
Abies	Trees	0	0	0	0	0	0	0,5	0	0
Quercus	Trees	22	26	21	19	9	11	21	0	0
Castanea	Trees	0	0	0	0	0	0	0	0	2
Fagus	Trees	0	0	0	1	0	0	0	0	0
Cf. Acer	Trees	0	0	0	0	0	1	0	0	0
Salix	Trees	0	1	0	0	0	0	0	0	2
Fraxinus	Trees	0	0	1	1	2	0	0	0	0
Tilia	Trees	7	9	4	8	1	1	3	0	0
Betula (tree)	Trees	21	25	6	10	9	4	6	18	0
Corylus	Trees	56	43	51	65	45	44	57	71	41
Alnus	Trees	42	37	32	36	24	34	41	5	5
Ulmus	Trees	16	10	16	23	13	8	7	0	3
Calluna vulgaris	Shrubs	0	0	1	1	1	2	0	0	0
Empetrum type	Shrubs	1	0	0	0	0	0	0	0	0
Vaccinium type	Shrubs	0	0	0	1	0	0	0	0	0
Cf. Ephedra	Shrubs	0	0	0	1	0	0	0	0	0
Juniperus	Shrubs	0	0	1	0	0	0	0	0	6
Betula (shrub)	Shrubs	0	0	0	0	0	0	0	31	165
Poaceae	Herbs	17	29	32	29	14	19	50	10	27
Hordeum type	Herbs	1	0	0	0	0	0	0	0	0
Cf. Pedicularis	Herbs	1	0	0	0	0	0	0	0	0
Sanguisorba minor type	Herbs	0	0	0	0	0	0	0	2	0
Monotropa hypopitys	Herbs	0	0	0	0	0	0	0	0	1
Apiaceae	Herbs	0	0	0	0	0	0	4	0	0
Artemisia	Herbs	0	0	0	0	0	0	0	0	3
Filipendula	Herbs	0	0	1	0	0	0	0	0	7
Cf. Filipendula	Herbs	0	0	0	0	0	0	1	0	0
Asteraceae	Herbs	0	0	0	0	0	1	0	0	0
Senecio type	Herbs	1	0	5	0	0	0	0	0	1
Cf. Valeriana	Herbs	0	0	0	0	0	0	1	0	0
Ballota type	Herbs	0	0	0	0	0	0	0	0	1
Rumex sp.	Herbs	0	2	0	0	0	1	0	0	0
Rumex acetosa type	Herbs	0	0	1	1	0	0	1	0	0
Lactuca	Herbs	0	0	0	0	0	1	0	0	0
Urticaceae	Herbs	0	1	0	0	0	0	0	0	2
Cannabinaceae	Herbs	0	0	0	0	0	0	1	0	0
Cf. Cannabinaceae	Herbs	0	1	0	0	2	0	0	0	0
Amaranthus	Herbs	8	0	7	1	3	4	0	0	0
Cyperaceae	Herbs	1	17	15	3	1	17	6	0	13
Hedera helix	Climbers	1	0	0	0	0	0	0	0	0
Typha latifolia type	Aquatics	0	0	0	1	0	0	9	0	0
Potamogeton	Aquatics	0	0	1	0	0	0	0	0	1
Nymphaea	Aquatics	0	0	2	0	0	1	2	0	0
Cf. Nymphaea	Aquatics	0	0	0	2	1	0	0	0	0
Sparganium type	Aquatics	12	56	53	45	7	19	16	0	2
Nuphar sp.	Aquatics	1	1	0	1	0	0	0	0	0
Utricularia	Aquatics	0	0	0	0	0	0	1	0	0
Myriophyllum verticillatum	Aquatics	0	2	0	0	0	0	0	0	0
Cf Myriophyllum	Aquatics	1	0	0	0	0	0	0	0	0
Alisma type	Aquatics	0	0	0	0	0	0	1	0	0
Sphagnum	Mosses	0	0	0	1	0	0	1	0	1
Mougeotia zygospore	Algae	0	0	0	0	0	0	0	0	1
Botryococcus	Algae	0	0	2	0	0	0	0	14	66
Diatom	Algae	2	3	1	0	0	0	0	0	0
Dinoflagellate	Algae	7	0	0	1	0	0	0	0	0
HdV-T900 Pediastrum	Algae	3	0	0	0	0	0	0	0	1
HdV-T58 Zygnemataceae zygospore	Algae	0	0	0	0	0	0	0	0	1
HdV-T128 Unidentified Alga	Algae	4	0	7	2	3	2	9	70	69
HdV-T132 Spyrogira spores	Algae	0	0	0	0	0	0	0	0	1
HdV-T760 Pediastrum	Algae	0	0	0	0	0	0	0	0	6
HdV-T314 Zygnema type	Algae	1	0	2	0	0	1	1	0	0
Pteropsida reticulate	Ferns	0	0	1	0	0	0	0	0	6
Pteropsida echinate	Ferns	0	0	1	0	0	1	0	0	0
Pteropsida scabrate	Ferns	0	0	0	0	0	0	0	12	0
Polypodium	Ferns	2	0	1	0	0	0	3	0	0
Pteridophyte spore	Ferns	0	0	2	0	0	0	0	0	0
Cf. Pteridium	Ferns	0	0	0	1	0	0	0	0	0
Pteropsida monolete	Ferns	18	4	32	18	17	16	783	429	386
Cf. HdV-T352 Arcella	Amoeba	0	0	0	1	0	0	0	0	0
HdV-T352 Arcella	Amoeba	0	0	0	4	0	0	0	0	0
Ascospores	Fungi	1	0	0	0	0	0	0	0	0
HdV-T89 Tetraploa	Fungi	0	0	2	0	0	0	0	0	0
Equisetum	Equisetopsida	2	0	0	0	0	0	0	0	0
HdV-T114 Scalariform plate	Plant part	0	0	0	0	0	0	0	0	1
Micro charcoal	Micro charcoal	0	0	0	0	1	0	0	0	0
Exotic	Exotic	32	27	13	18	333	25	36	28	47
Unidentified pollen	Unidentified pollen	13	5	28	22	0	20	29	17	120

Table 2 Counted VVP pollen in percentages of total land pollen. (Table by Dr. I.M. Kamerling & A. Lynch)

Code	Taxa	Group	919.5	920.5	930.5	940.5	950.5	959.5	969.5	983.5	984.5
Pic	Picea	Trees	0	0,5	0	0	0	0	0	0	0
Pin	Pinus	Trees	4,2	1,9	3,7	1,2	6,1	3	6,6	38	22
Abie	Abies	Trees	0	0	0	0	0	0	0,2	0	0
Quer	Quercus	Trees	10,8	12,6	10,4	9,4	6,8	7,2	9,8	0	0
Cast	Castanea	Trees	0	0	0	0	0	0	0	0	0,6
Fagu	Fagus	Trees	0	0	0	0,5	0	0	0	0	0
Acer	Cf. Acer	Trees	0	0	0	0	0	0,7	0	0	0
Sal	Salix	Trees	0	0,5	0	0	0	0	0	0	0,6
Frax	Fraxinus	Trees	0	0	0,5	0,5	1,5	0	0	0	0
Til	Tilia	Trees	3,4	4,4	2	4	0,8	0,7	1,4	0	0
Bet.tree	Betula tree	Trees	10,3	12,1	3	4,9	6,8	2,6	2,8	8,1	0
Cor	Corylus	Trees	27,5	20,9	25,3	32,1	34,1	28,9	26,7	32,1	11,5
Aln	Alnus	Trees	20,6	18	15,9	17,8	18,2	22,3	19,2	2,3	1,4
Ulm	Ulmus	Trees	7,9	4,9	7,9	11,4	9,8	5,2	3,3	0	0,8
Call	Calluna vulgaris	Shrubs	0	0	0,5	0,5	0,8	1,3	0	0	0
Emp	Empetrum type	Shrubs	0,5	0	0	0	0	0	0	0	0
Vacc	Vaccinium type	Shrubs	0	0	0	0,5	0	0	0	0	0
Eph	Cf. Ephedra	Shrubs	0	0	0	0,5	0	0	0	0	0
Juni	Juniperus	Shrubs	0	0	0,5	0	0	0	0	0	1,7
Bet.Shr	Betula shrub	Shrubs	0	0	0	0	0	0	0	14	46,2
Poa	Poaceae	Herbs	8,4	14,1	15,9	14,3	10,6	12,5	23,4	4,5	7,6
Hord	Hordeum type	Herbs	0,5	0	0	0	0	0	0	0	0
CPed	Cf. Pedicularis	Herbs	0,5	0	0	0	0	0	0	0	0
Sangui	Sanguisorba minor type	Herbs	0	0	0	0	0	0	0	0,9	0
Monot	Monotropa hypopitys	Herbs	0	0	0	0	0	0	0	0	0,3
Apia	Apiaceae	Herbs	0	0	0	0	0	0	1,9	0	0
Arte	Artemisia	Herbs	0	0	0	0	0	0	0	0	0,8
Fil	Filipendula	Herbs	0	0	0,5	0	0	0	0	0	2
cf.Fil	Cf. Filipendula	Herbs	0	0	0	0	0	0	0,5	0	0
Aster	Asteraceae	Herbs	0	0	0	0	0	0,7	0	0	0
Senec	Senecio type	Herbs	0,5	0	2,5	0	0	0	0	0	0,3
cf.Valer	Cf. Valeriana	Herbs	0	0	0	0	0	0	0,5	0	0
Ball	Ballota type	Herbs	0	0	0	0	0	0	0	0	0,3
Rum.sp	Rumex sp.	Herbs	0	1	0	0	0	0,7	0	0	0
Rum.ace	Rumex acetosa type	Herbs	0	0	0,5	0,5	0	0	0,5	0	0
Lact	Lactuca	Herbs	0	0	0	0	0	0,7	0	0	0
Urtic	Urticaceae	Herbs	0	0,5	0	0	0	0	0	0	0,6
Cannab	Cannabinaceae	Herbs	0	0	0	0	0	0	0,5	0	0
cf.Cannab	Cf. Cannabinaceae	Herbs	0	0,5	0	0	1,5	0	0	0	0
Amaran	Amaranthus	Herbs	3,9	0	3,5	0,5	2,3	2,6	0	0	0
Cypera	Cyperaceae	Herbs	0,5	8,3	7,4	1,5	0,8	11,1	2,8	0	3,6
Hedhel	Hedera helix	Climbers	0,5	0	0	0	0	0	0	0	0
Typha	Typha latifolia type	Aquatics	0	0	0	0,5	0	0	4,2	0	0
Potam	Potamogeton	Aquatics	0	0	0,5	0	0	0	0	0	0,3
Nympha	Nymphaea	Aquatics	0	0	1	0	0	0,7	0,9	0	0
cf.Nymph	Cf. Nymphaea	Aquatics	0	0	0	1	0,8	0	0	0	0
Sparga	Sparganium type	Aquatics	5,9	27,2	26,3	22,2	5,3	12,5	7,5	0	0,6
Nuphar	Nuphar sp.	Aquatics	0,5	0,5	0	0,5	0	0	0	0	0
Utricu	Utricularia	Aquatics	0	0	0	0	0	0	0,5	0	0
Myr.vert	Myriophyllum verticillatum	Aquatics	0	1	0	0	0	0	0	0	0
cf.Myr	Cf Myriophyllum	Aquatics	0,5	0	0	0	0	0	0	0	0
Alisma	Alisma type	Aquatics	0	0	0	0	0	0	0,5	0	0
Sphag	Sphagnum	Mosses	0	0	0	0,5	0	0	0,5	0	0,3
Moug	Mougeotia zygospore	Algae	0	0	0	0	0	0	0	0	0,3
Botry	Botryococcus	Algae	0	0	1	0	0	0	0	6,3	18,5
Diatom	Diatom	Algae	1	1,5	0,5	0	0	0	0	0	0
Dinof	Dinoflagellate	Algae	3,4	0	0	0,5	0	0	0	0	0
T900.Ped	Pediastrum algae HdV-900	Algae	1,5	0	0	0	0	0	0	0	0,3
T58.Zyg	Type 58 Zygnemataceae zygospore	Algae	0	0	0	0	0	0	0	0	0,3
T128.alg	Type 128 Unid alga	Algae	2	0	3,5	1	2,3	1,3	4,2	31,7	19,3
T132.Spy	type 132 Spyrogira	Algae	0	0	0	0	0	0	0	0	0,3
T760.Ped	Type 760 Pediastrum	Algae	0	0	0	0	0	0	0	0	1,7
T314.Zyg	Zygnema type 314	Algae	0,5	0	1	0	0	0,7	0,5	0	0
Pter.ret	Pteropsida reticulate	Ferns	0	0	0,5	0	0	0	0	0	1,7
Pter.ech	Pteropsida echinate	Ferns	0	0	0,5	0	0	0,7	0	0	0
Pter.scab	Pteropsida scabrate	Ferns	0	0	0	0	0	0	0	5,4	0
Polyp	Polypodium	Ferns	1	0	0,5	0	0	0	1,4	0	0
Pterid	Pteridophyte spore	Ferns	0	0	1	0	0	0	0	0	0
cf.Pterid	Cf. Pteridium	Ferns	0	0	0	0,5	0	0	0	0	0
Pter.mon	Pteropsida monolete	Ferns	8,8	1,9	15,9	8,9	12,9	10,5	366,7	194,1	108
cf.Arcel	Cf. Arcella	Amoeba	0	0	0	0,5	0	0	0	0	0
T352.Arc	Type 352 Arcella	Amoeba	0	0	0	2	0	0	0	0	0
Asc	Ascospores	Fungi	0,5	0	0	0	0	0	0	0	0
T89.Tetr	Type 89 Tetraploa	Fungi	0	0	1	0	0	0	0	0	0
Equi	Equisetum	Equisetopsida	1	0	0	0	0	0	0	0	0
T114.Scal	Type 114 Scalariform plate	Plant part	0	0	0	0	0	0	0	0	0,3
Char	Micro charcoal	Micro charcoal	0	0	0	0	0,8	0	0	0	0
Lyc	Exotic	Exotic	15,7	13,1	6,5	8,9	252,3	16,4	16,9	12,7	13,1
Unid	Unidentified	Unidentified pollen	6,4	2,4	13,9	10,9	0	13,1	13,6	7,7	33,6
SUM(a)	Trees	Sum	84,8	75,7	68,7	81,7	84,1	70,5	70	80,5	36,8
SUM(b)	Shrubs	Sum	0,5	0	1	1,5	0,8	1,3	0	14	47,8
SUM(c)	Herbs	Sum	14,3	24,3	30,3	16,8	15,2	28,2	30	5,4	15,4
SUM(d)	Climbers	Sum	0,5	0	0	0	0	0	0	0	0
SUM(e)	Aquatics	Sum	6,9	28,6	27,8	24,2	6,1	13,1	13,6	0	0,8
SUM(f)	Mosses	Sum	0	0	0	0,5	0	0	0,5	0	0,3
SUM(g)	Algae	Sum	8,4	1,5	6	1,5	2,3	2	4,7	38	40,6
SUM(h)	Ferns	Sum	9,8	1,9	18,4	9,4	12,9	11,1	368,1	199,5	109,7
SUM(i)	Amoeba	Sum	0	0	0	2,5	0	0	0	0	0
SUM(j)	Fungal	Sum	0,5	0	1	0	0	0	0	0	0
SUM(k)	Equisetopsida	Sum	1	0	0	0	0	0	0	0	0
SUM(l)	Plant fragments	Sum	0	0	0	0	0	0	0	0	0,3
SUM(m)	Microcharcoal	Sum	0	0	0	0	0,8	0	0	0	0
SUM(n)	Spike	Sum	15,7	13,1	6,5	8,9	252,3	16,4	16,9	12,7	13,1
SUM(o)	Unidentified pollen	Sum	6,4	2,4	13,9	10,9	0	13,1	13,6	7,7	33,6
SSUM(Z)	Total Land Pollen	Sum(a,b,c,d)	203,5	206	201,5	202,5	132	152,5	213,5	221	357,5

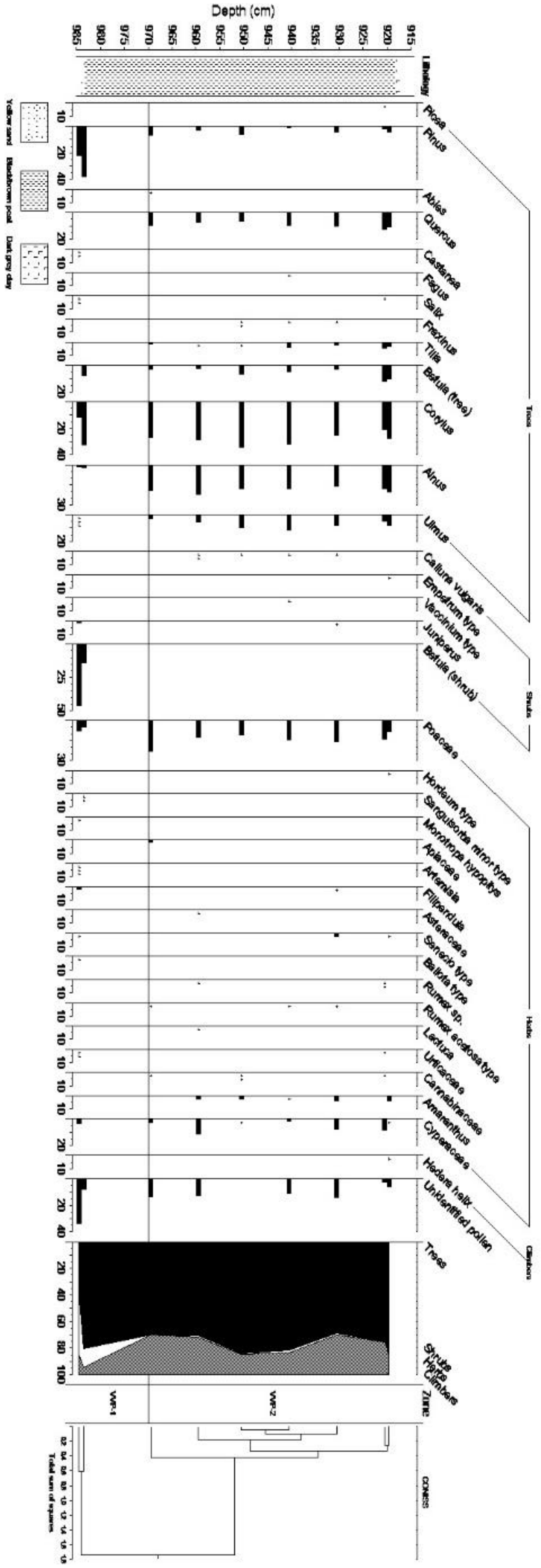

Figure 9 VVP pollen diagram of land pollen. (Figure by Dr. I.M. Kamerling & A. Lynch)

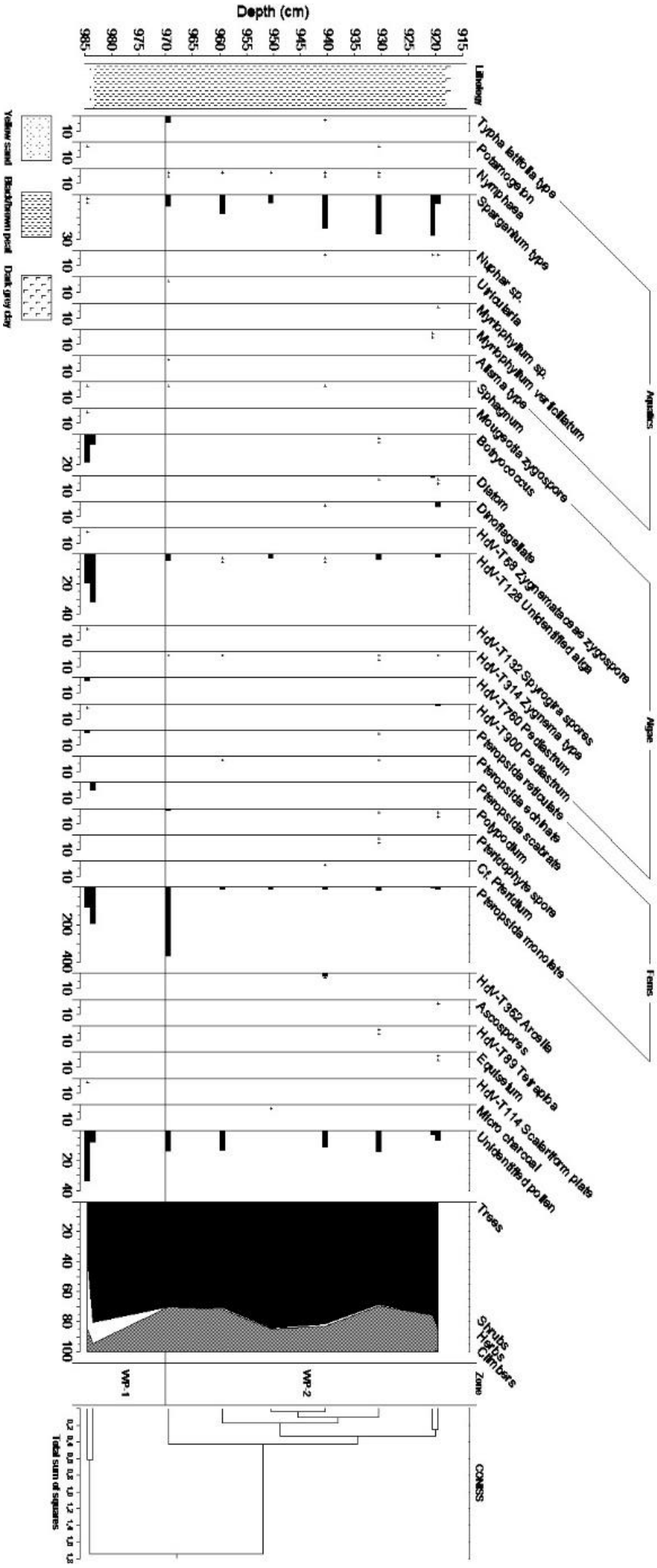

Figure 10 VVP pollen diagram of remaining pollen & spores. (Figure by Dr. I.M. Kamerling & A. Lynch)

4. Discussion

4.1 Local pollen assemblage zones analysis

The results showed two distinct local pollen assemblage zones which are designated as LPAZ VVP-1 and LPAZ VVP-2. These two zones will now be analyzed separately in order to see what the landscape of the Vrouw Vennepolder looked like during each zone.

4.1.1 LPAZ VVP-1

LPAZ VVP-1 mainly belongs to the sandy sediments that were deposited by the Rhine at the end of the Pleistocene. The high amounts of *Pinus* and fair amounts of *Betula* therefore make sense seen as they are both coniferous pioneer species that would have been among the first trees to start growing in the Netherlands at the end of the Pleistocene. (Weeda, 1985, p. 54-56, p. 87-89) The presence of *Salix* is also unsurprising seen as this is also a pioneer. It likes to grow in wet soils next to water. (Weeda, 1985, p. 64) The large amounts of *Corylus* and the trace amounts of *Alnus*, *Ulmus* and *Castanea* however indicate that deciduous trees were already starting to grow at this point in time. *Corylus* and *Castanea* prefer damp soils and would therefore probably have been near the water but not directly next to it like the *Salix*. (Weeda, 1985, p. 100-104) *Ulmus* on the other hand needs well-aired soils and would probably be further away from the water. (Weeda, 1985, p. 118-119) The presence of *Alnus* indicates that the marshes that would soon appear on mass may have already began to form. (Weeda, 1985, p. 93-94)

The fair amount of shrubs are represented by *Betula* and *Juniperus* which are both pioneer species and probably indicate the remaining presence of the Pleistocene steppe landscape. This is also aided by *Juniperus's* preference for dry soils which places it far from the water. (Weeda, 1985, p. 57-58, p. 87-89) The significant presence of *Poaceae* is hard to interpret because it includes so many different grasses, but it could represent grasses from the steppe or it could be reeds standing near the edge of the water. (Weeda & Deursen, 1994, p. 46-49) The *Cyperaceae's* and *Filipendula's* preference for wet soils indicate that they were probably located right next to the water's edge. (Weeda & Deursen, 1987, p. 59-61, 1994, p. 245) *Artemisia* is a clear steppe plant and would therefore have grown on the steppe and it is likely that the other herbs that are present here were also located on this steppe. (Weeda & Deursen, 1991, p. 80-82) This includes *Sanguisorba minor type*, *Urticaceae*, *Ballota type*, *Senecio type* and *Monotropa hypopitys*. (Weeda, 1985, p. 125-126; Weeda & Deursen, 1987, p. 76-77, 1988, p. 28-29, p. 163-164, 1991, p. 95))

The trace amounts of *Sparganium type* indicate there was shallow flowing water nearby which would probably be a shallow part of the Rhine or one of its tributaries. (Weeda & Deursen, 1994, p. 235-236) The trace amounts of *Potamogeton* however suggest the potentiality of a salt marsh and *HdV-T114* also suggests some sort of marine influence. (Weeda & Deursen, 1991, p. 242) Trace amounts of *Sphagnum* could potentially indicate some peat formation has already begun but it is not definitive. (Weeda, 1985, p. 8) The *Botryococcus* and *HdV-T128* dominated algae all seem to point towards fresh water that is eutrophic to mesotrophic in nature. (Geel et al, 1980, p. 407) This is another indication for a nearby river or lake. The large amount of *Pteropsida* is difficult to interpret because these ferns comprise so many different types meaning they could have grown on the steppe, the forest floor or the water's edge. (Weeda, 1985, p. 26-27)

The picture that emerges is a landscape in which coniferous *Pinus* forests are starting to become mixed deciduous forests with large amounts of *Corylus* and in which the steppe still covers significant parts of the landscape. There is clearly water nearby either in the form of a lake or a river with the Rhine or one of its tributaries being a likely candidate.

4.1.2 LPAZ VVP-2

LPAZ VVP-2 mainly belongs to the peat sediments of the Early Holocene. In comparison to LPAZ VVP-1 the forests are now much more mixed and largely deciduous in nature. The coniferous *Pinus* and *Betula* trees still remain in noticeable numbers along with trace amounts of other coniferous trees like *Picea* and *Abies*, but the deciduous trees clearly dominate the forests now. (Weeda, 1985, p. 54) *Corylus* and *Alnus* are the two dominant deciduous trees but there are also significant amounts of *Quercus*, *Ulmus* and *Tilia* indicating the mixed nature of these forests. Trace amounts of deciduous trees like *Fraxinus*, *Fagus* and *Salix* further solidify how mixed these forests are. (Weeda, 1985, p. 102-106; Weeda & Deursen, 1988, p. 77-80) The large amounts of *Alnus* are a strong indication that marshes now occupy large parts of the landscape which makes sense given the peat sediments that LPAZ VVP-2 belong to.

Shrubs now only occur in trace amounts indicating that the Pleistocene steppe is gone. *Juniperus* is the only steppe shrub that remains whereas the other shrubs like *Calluna vulgaris*, *Empetrum type* and *Vaccinium type* all indicate the presence of a high moor which makes sense in relation to the peat sediments. (Weeda & Deursen, 1988, p. 37-39, p. 46-47, p. 53-55) Herbs play a much larger role now and are dominated largely by *Poaceae* with *Cyperaceae* and *Amaranthus* also occurring in significant amounts. The large number of *poaceae* likely represent reeds along the water's edge where they are joined by *Cyperaceae* and trace amounts of *Filipendula*, *Asteraceae* and *Cannabinaceae* which all grow at the water's edge. (Weeda, 1985, p. 123-124; Weeda & Deursen, 1991, p. 38) Trace amounts of *Hordeum type* and *Rumex acetosa type* indicate the lasting presence of some sort of grassland or drier soils whereas *Amaranthus* and the trace amounts of *Apiaceae*, *Senecio type*, *Rumex sp. Lactuca* and *Urticaceae* are difficult to place in a specific location. (Weeda, 1985, p. 145-147, p. 173-174; Weeda & Deursen, 1987, p. 243-244, 1991, p. 177-178, 1994, p. 135-136) A single occurrence of a climber is also present here in the form of *Hedera helix*. (Weeda & Deursen, 1987, p. 240)

Aquatics have increased significantly and mainly due to the large numbers of *Sparganium type* which indicate shallow oligotrophic water that is flowing which means that a river is likely in the area. (Weeda & Deursen, 1994, p. 235-236) *Typha latifolia type* is a marshplant that occurs in respectable numbers here which makes sense given the *Alnus* marshes. (Weeda & Deursen, 1994, p. 235) *Nymphea* also occurs in respectable numbers and indicates the presence of deep calm water. (Weeda, 1985, p. 216-218) The other aquatics occur in trace amounts with *Potamogeton* indicating a salt marsh, *Nuphar sp.* indicating oligotrophic water, *Utricularia* indicating stagnant water, *Alisma type* growing at the water's edge and *Myriophyllum sp.* and *Myriophyllum verticillatum* being difficult to place. (Weeda, 1985, p. 216-219; Weeda & Deursen, 1987, p. 234-236, 1988, p. 247-248, 1991, p. 222-226) The presence of *Sphagnum* is yet another indicator of peat given that it forms in peat. The amounts of algae are severely reduced with only *HdV-T128* producing respectable numbers. *HdV-T128*, *Botryococcus*, *HdV-T314* and *HdV-T900* together seem to indicate the presence of shallow fresh water that is eutrophic to mesotrophic in nature which could be the marshes themselves or a nearby river. (Geel et al, 1980, p. 403, p. 427) The traces of *Diatom* and *Dinoflagellate* are difficult to interpret.

In general fern numbers are low with *Pteropsida monolete* making up the main bulk of the numbers. Other *Pteropsida* versions along with *Polypodium*, *Pteridophyte spore* and *Cf. Pteridium* only occur in trace amounts. Given that ferns are very diverse it is hard to say where they were located but it is likely that they either lined the forest floor, the marshes or the water's edge. (Weeda, 1985, p. 31, p. 49-50) The amoeba *HdV-T352* grows in *sphagnum* peat and therefore its presence here makes a lot of sense. (Geel et al, 1980, p. 434) The presence of *Equisetum* also makes sense seen as it grows in shallow water. (Weeda, 1985, p. 18-19) The single occurrence of micro charcoal here could be a sign of either natural or intentional burning. The fungus *Ascospores* is also present and so is *HdV-T89*.

The picture that emerges is a landscape in which the coniferous *Pinus* forests have been replaced with mixed mainly deciduous forests where *Corylus* still plays a dominant role. The steppe has disappeared and *Alnus* marshes have appeared as a dominant force in the landscape. There is clearly water nearby and it is most likely a river with the Rhine or one of its tributaries being the likely source.

4.2 Refining the timescale

4.2.1 Sediments & biostratigraphy

The results will now be compared to previous knowledge in order to try and see how well they line up with what is already known and to try and see what time periods are actually being dealt with here.

The boundary between the sand sediments and the peat sediments was located at 984 cm below ground level and the boundary between the peat sediments and the clay sediments was located at 920 cm below ground level with everything in between consisting of peat sediments. Based on the landscape background the transition between sand and peat very clearly indicates the transition from the Pleistocene sand to the Holocene basal peat and should have therefore occurred around 10.000 BP. (Huizer et al., 2011, p. 10) The landscape background also has a clear explanation for the transition from the basal peat to the tidal clay in the form of the sea becoming a bigger influence on the community of Kaag en Braassem at around 8000 BP. (Huizer et al., 2011, p. 11)The sediments therefore indicate a sequence of around 2000 years right at the beginning of the Holocene.

The pollen diagrams show two distinct LPAZs throughout the sampled sequence. LPAZ VVP-1 shows a *Pinus* dominated coniferous forest that is transitioning into a mixed deciduous forest. The steppe landscape is also still prominent but is starting to disappear. LPAZ VVP-2 on the other hand displays a mixed deciduous forest in combination with *Alnus* marshes. The biostratigraphy of LPAZ VVP-1 correlates well with the biostratigraphy of the Younger Dryas at the very end of the Pleistocene. The large amounts of *Pinus* and *Betula* and the large amounts of shrubs and herbs both make sense for this time period. The general absence of many other types of trees also lines up well with the Younger Dryas. (Woelders et al., 2016, p. 183) The large amounts of *Corylus* in LPAZ VVP-1 on the other hand seem out of place for this time period and correlate better with later periods like the Boreal. (Woelders et al., 2016, p. 185) Their presence here either means that *Corylus* appeared early in the Vrouw Vennepolder compared to the general picture of the Netherlands or it means that this LPAZ incorporates the transition from the Younger Dryas to the Preboreal, a time period in which *Corylus* are known to have been present. (Brouwer, 2011, p. 149-150)

The biostratigraphy of LPAZ VVP-2 correlates well with the biostratigraphy of the Boreal period. This is interesting because it suggests a hiatus in the sampled sequence where the Preboreal period should have taken place. Given that the cored samples were undisturbed, it seems that the Preboreal period either didn’t deposit any sediments or that they were later eroded away. The correlation to the Boreal period is mainly visible in the large amounts of *Corylus* that are present in LPAZ VVP-2.

Although *Corylus* is also present in the Preboreal, a dominant presence of *Corylus* correlates well with the Boreal period which is definitely the case here. (Woelders et al., 2016, p. 185) The diversification of the forest in LPAZ VVP-2 at the hand of significant amounts of specifically *Quercus*, *Ulmus* and *Tilia* in addition to the *Pinus*, *Betula* and *Corylus* is also a clear indication of the Boreal period. Peat formation is also known to have started during the Boreal period which of course also makes sense here given the peat sediments that LPAZ VVP-2 belongs to. (Brouwer, 2011, p. 150) In the same way that the large amounts of *Corylus* in LPAZ VVP-1 seemed out of place, similarly do the large amounts of *Alnus* in LPAZ VVP-2 seem out of place. Although *Alnus* was definitely present during the Boreal, its dominance in the vegetational assemblage correlates with the Atlantic period. (Woelders et al., 2016, p. 185) However given that LPAZ VVP-2 covers roughly 60 cm of peat sediments which all display the large amounts of *Alnus*, it is unlikely that the dominant presence of *Alnus* can be explained by correlating the entirety of LPAZ VVP-2 to the transition between the Boreal and the Atlantic. It is therefore far more likely that the *Alnus* marshes just appeared early in the Vrouw Vennepolder. The increase in *Poaceae*, *Cyperaceae* and marsh herbs in LPAZ VVP-2 can also be explained by these *Alnus* marshes. The sharp decrease in *Pinus* also correlates better with the Atlantic period as does the, albeit limited, presence of *Hedera* at the end of LPAZ VVP-2 but these aren't strong correlations. Overall given that the forests in LPAZ VVP-2 are dominated by *Corylus* instead of *Quercus* it is clear that LPAZ VVP-2 belongs to the Boreal and not the Atlantic. (Brouwer, 2011, p. 150-151)

Based on the sediments and the biostratigraphy it appears that the sampled sequence started at the end of the Pleistocene during the Younger Dryas and maybe incorporated the transition in to the Holocene Preboreal. After a hiatus during the Preboreal period it then continued on in the Boreal period where it likely ended around the transition from the Boreal to the Atlantic.

4.2.2 Sea-level curve

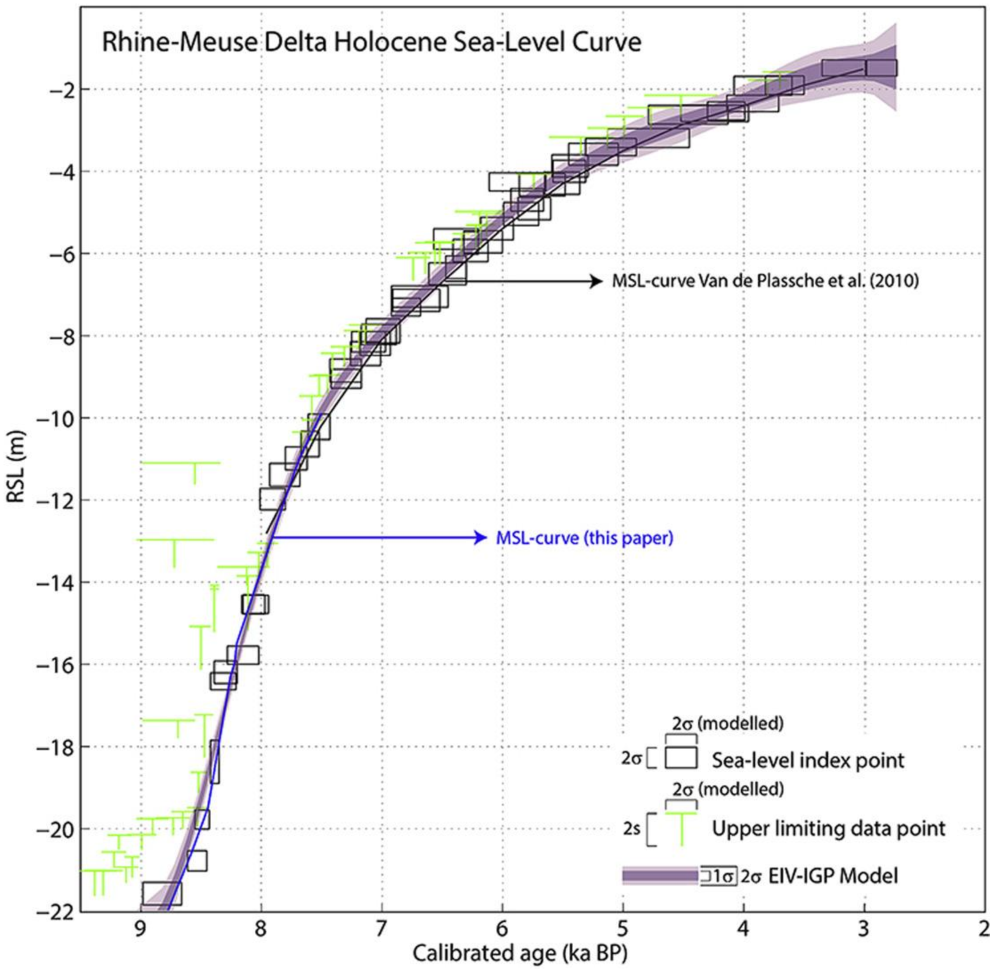

Figure 11 Rhine-Meuse delta Holocene sea-level curve. (Hijma & Cohen, 2019, p. 78)

By comparing the depths of the sediments to the sea-level curve (See Figure 11) of the Rhine-Meuse delta it is possible to get a general idea of the timeframe that the sampled sequence represents. The ground level of coring 51 was located at -2.195 m NAP and the sediments were located between 919 cm deep and 985 cm deep. This means that the sediments were between -11,385 m NAP and -12,045 m NAP deep. According to the sea-level curve this gives the sediments an age of around 7700-8000 BP. This is interesting because not only does this imply a much younger age of the sediments, it also suggests that the sampled sequence only covers around 300 years whereas the sediments and biostratigraphy indicate a length of around 2000 years. The apparent shorter time span of the sequence is possibly explained by the compression of the peat layer over time which then of course would interfere with the accurate measurement of the top of the peat layer therefore causing the sequence to appear shorter when correlated with the sea-level curve than it actually was. (Huizer et al., 2011, p. 11) The hiatus of sediments from the Preboreal might also be responsible for throwing of the accuracy of the sea-level curve dates. These issues would however not affect the depth of the deepest sand sediments and therefore accounting for the compression and the hiatus would not give the sequence an older date. This young age puts the sequence well in to the Atlantic period whereas the sediments and biostratigraphy indicate its more likely that the sequence took place between the end of the Younger Dryas and the end of the Boreal. Given the difficulty of getting accurate dates using the sea-level curve method, it is probably best to lean more towards the timeline provided by the sediments and the biostratigraphy.

4.3 Human presence in the Vrouw Vennepolder

4.3.1 Resources & ecological challenges

A human presence in the Vrouw Vennepolder during the Late Pleistocene and Early Holocene is difficult to prove, but some speculations can be made on how suitable the landscape would have been for humans and that can indicate whether or not they are likely to have been there or not.

LPAZ VVP-1 would have occurred at the very end of the Weichselien during the Younger Dryas, a period during which almost the entire Benelux appears to have been unoccupied according to current knowledge due to the colder conditions. (De Bie & Vermeersch, 1998, p. 39) Yet the mostly coniferous *Pinus* forest and steppe that characterized LPAZ VVP-1 would have provided an abundance of resources for Late Paleolithic or Early Mesolithic groups. The steppe would have provided access to the large steppe animals like horse, bovids and maybe even still reindeer and mammoths in the beginning. (De Bie & Vermeersch, 1998, p. 30) The coniferous forests would have provided access to animals like roe deer, red deer and wild boar as well as plenty of foraging opportunities which would have been important parts of the diets of particularly Mesolithic groups. The large amounts of *Corylus* nuts would have been especially useful. The lake and river that seem to be present would also have given them the option of catching fish and birds which had also become an important part of Mesolithic diets. (Brouwer, 2011, p. 68-69)

Aside from the resources that it provided, the environment of LPAZ VVP-1 would also have affected potential occupants in different ways. During this time the sea would still have been far away and is therefore unlikely to have influenced the area much but the river that was clearly present would have had a great influence on potential occupants. The rivers of the Younger Dryas were aggrading braided rivers that had a high peak discharge, a large bedload and a small suspended load. (Berendsen & Stouthamer, 2000, p. 320-322) This means the river would have been very active and unstable which would have made it difficult for people to live right next to it given the risk of flooding during the peak discharge. The aggrading nature of the river would also have prevented people from living right next to the river given the large amounts of sedimentation that would have taken place. The high peak discharge also means that most of the rainwater would have been transported away very quickly contributing to a very low groundwater table. On the one hand this would have provided plenty of dry ground to build a settlement on but on the other hand it might have caused problems in terms of providing a consistent reliable source of fresh drinking water. (Berendsen & Stouthamer, 2000, p. 320-322) Given the dry nature of the Younger Dryas and the relatively open landscape of the steppe, the wind also played an important role during this time period. The wind would have carried sand from for instance the occasionally dried out floodplain of the river and deposited it across the landscape. This caused small dunes to be formed in certain areas which of course provided the perfect location for a settlement given the protection it offered from the river. (Berendsen & Stouthamer, 2000, p. 320-322)

LPAZ VVP-2 would have occurred during the Boreal period, a period that as opposed to the Younger Dryas is known to have had human occupation across the entirety of the Benelux. (De Bie & Vermeersch, 1998, p. 39) The question remains however whether specifically the Vrouw Vennepolder was occupied or not. The mixed deciduous forests and *Alnus* marshes of LPAZ VVP-2 would have provided plenty of opportunities for Mesolithic groups. The steppe animals would no longer be available at this point but the mixed deciduous forests would still have provided access to roe deer, red deer and wild boar in addition to an increased amount of foraging opportunities with *Corylus* nuts still representing the most obvious supply. (Brouwer, 2011, p. 68-69; De Bie & Vermeersch, 1998, p. 30) In addition the *Alnus* marshes would have provided even more foraging opportunities as well as different kinds of wetland creatures like fish and birds. (Brouwer, 2011, p. 72-73) The salt marsh clay sediments near the top of the sampled sequence indicate that the sea was gaining influence in the Vrouw Vennepolder at the end of LPAZ VVP-2 and it probably roughly coincides with the start of the Atlantic period. This would have also meant the transition to Late Mesolithic groups who largely operated the same way as the preceding Early Mesolithic groups only with a bigger focus on foraging and marine resources. (Brouwer, 2011, p. 78-79) These marine resources would have been very close given the depositions of clay by the sea and therefore would have provided another reason to forage in this area.

The environment of LPAZ VVP-2 would also have affected potential occupants in different ways. The warming up of the climate and the associated increase in vegetation affected the rivers immensely. The peak discharge decreased and so did the bedload, whereas the suspended load increased. These changes caused the rivers to become largely straight or meandering and deeply incising as opposed to the braided aggrading rivers of the Younger Dryas. (Berendsen & Stouthamer, 2000, p. 322) It also appears that the Rhine-Meuse delta now consisted of a small amount of large river channels as opposed to the large amount of small river channels from before indicating a large decrease in overall discharge. Many of these smaller channels that were previously active now became the locations of peat formation. (Berendsen & Stouthamer, 2000, p. 322) Given the now incising nature of the river and the decrease in discharge, it would have been easier to live right next to the river at this time. This is because the incising of the river means that sedimentation isn't occurring along the river and because of the lower discharge the likelihood of flooding is also reduced. The water table would have been a lot higher during LPAZ VVP-2 than during LPAZ VVP-1 given the warming effect of the Holocene. This is also clearly shown in the fact that LPAZ VVP-2 belongs to peat sediments which of course only forms with a high water table. (Berendsen & Stouthamer, 2000, p. 322) This high water table would have made it very difficult for people to find a suitable place for a settlement because it is of course very unlikely that they decided to build a settlement in the middle of an *Alnus* marsh. The forests would be a much more likely place for a settlement at this time. Due to the more closed vegetation of this zone and the wetter conditions of the Holocene the wind is unlikely to have been able to play a large role here in the way that it was able to in the Younger Dryas. At first the sea would also not have played a massive role in the area, but based on the salt marsh clay sediments at the end of LPAZ VVP-2 it is clear that at the end of the sequence the sea was a dominant factor in the area. This would have meant regular flooding from the sea and the presence of salt water in the system. (Huizer et al., 2011, p. 11) The regular flooding would have made the area unsuitable for building a settlement and the salt water might have made it difficult to access fresh drinking water.

It is clear that throughout LPAZ VVP-1 and LPAZ VVP-2 there is no lack of resources which means that Paleolithic and Mesolithic groups should have been able to exploit the Vrouw Vennepolder's resources. The ecological challenges posing actual settlements within the Vrouw Vennepolder are more concerning. The sediments from the coring along with information from the pollen analysis indicate that the area in the immediate vicinity of the coring changed from the floodplain of a river to an Alnus marsh and then to a salt marsh. All of these environments are not suitable for building a settlement so this might mean that although people might have frequented the Vrouw Vennepolder for its resources, they didn't build any settlements in it. They probably built their settlements on drier grounds somewhere nearby like the forests or potentially a small dune.

4.3.2 Difficulties of providing evidence

Theoretically it thus seems likely that people interacted in some way with the Vrouw Vennepolder, so why is there no evidence for it? So far no archaeological remains have been found in the entire community of Kaag en Braassem dating to the Paleolithic or the Mesolithic even though the landscape would have allowed it. (Huizer et al., 2011, p. 14) The VVP corings also didn't uncover any archaeological remains from these time periods. (Mol, 2023) The problem is twofold. First of all there hasn't been any real attempt to find archaeological remains in the Vrouw Vennepolder given the great depths at which these time periods reside. (Huizer et al., 2011, p. 14) Second of all Palaeolithic and Mesolithic groups leave very little traces that are detectable, especially using methods like coring and palynology which are the only types of research that have really been done in the Vrouw Vennepolder so far. Their usually small and temporary settlements are very hard to detect and would basically require you to stick the corer right in to them in order to notice them. Animal remains dating to these time periods are very rare and would also be essentially undetectable by coring and palynology. The same detection difficulties would apply to tools. (Woelders et al., 2016, p. 177) Large amounts of microscopic charcoal could indicate fire activity, but given that there is only one occurrence of microscopic charcoal in this dataset it is of no use here. Charred macrofossils like charred *Corylus* nuts could also be an indication of human burning, but that would require macrofossil studies. (Woelders et al., 2016, p. 187) Bulk samples of peat that could possibly contain macrofossils were taken during sampling, but there was not enough time to incorporate them into this research.

4.3.3 Indicator taxa in pollen diagrams

There are some instances of pollen diagrams being used to detect Early Mesolithic peoples impact on the environment. (Woelders et al., 2016, p. 177-178) This usually revolves around certain indicator taxa like for instance *Corylus*. There is evidence that Mesolithic people burned woodland in order to open up the landscape and stimulate *Corylus* to grow in pursuit of the *Corylus's* nuts which were an ideal staple food given their richness in protein and their high fat content. (Bos & Urz, 2003, p. 32-33) It is even suggested that this human practice is what caused *Corylus* to spread across Europe so fast at the beginning of the Holocene. This is based on a pattern which has been observed across several sites in which the first appearance of Mesolithic people, large amounts of macroscopic charcoal and the rise of *Corylus* all occur at the same time. (Bos & Urz, 2003, p. 32-33) In a pollen diagram you would then see a reduction in arboreal pollen as woodland is burned down, an increase in shrubs and herbs as they will be the first to grow on the cleared woodland floor and then an increase in *Corylus* numbers as they take over the area. (Bos & Urz, 2003, p. 32-33) It is difficult to say whether this pattern can be observed in the pollen diagram of this research. The beginning of LPAZ VVP-1 definitely shows a high amount of herbs and shrubs in combination with a moderate amount of *Corylus* and a moderate amount of other tree taxa, whereas the end of LPAZ VVP-1 shows a lower number of herbs and shrubs in combination with a high amount of *Corylus* and a higher amount of other tree taxa. It is definitely possible that deliberate burning to favor *Corylus* occurred here but without the sequence leading up to LPAZ VVP-1 it is difficult to say for sure. In short it is definitely possible and probably likely that Paleolithic or at least Mesolithic groups were active in the Vrouw Vennepolder, but using only coring data and palynological data there is as of yet no clear evidence for it.

4.4 Limitations of research

The limitations of this research are firstly related to the problems inherent with pollen studies. Different plants produce different amounts of pollen based mainly on their dispersal strategies like for instance wind dispersal, insect dispersal or water dispersal. This means that plants that disperse their pollen by wind tend to be overrepresented in the pollen count whereas plants that disperse their pollen by insects or water tend to be underrepresented. Most prominent taxa in the pollen diagrams here are wind pollinators, but there are also some insect pollinating taxa present albeit mostly in lesser quantities. (Cappers & Neef, 2012, p. 25) The distance at which different plants can disperse their pollen also varies which makes it very difficult to tell whether pollen belong to the local, regional or supra-regional vegetation. This makes it difficult to paint a clear picture of the Vrouw Vennepolder because you don't know over what distance all the different taxa are present. (Cappers & Neef, 2012, p. 25) The preservation of pollen is also an issue. The peat and clay sediments in general provide good preservation for the pollen whereas the sand sediments are much worse at preserving pollen which is why the amount of unidentified pollen counted in the sand sediments is much higher. (Cappers & Neef, 2012, p. 26)

The limitations related to dating the sampled sequence are clear. Using the depths of the sediments and the sea-level curve to provide accurate dates is difficult and the sediments and biostratigraphy are more useful for indicating the general time periods as opposed to providing actual dates. It is obvious that radiocarbon dating will have to be used in order to provide an accurate dating, but finding something to radiocarbon date is difficult using only corers. The hope is that there are some datable macrofossils in the bulk samples that were taken from the peat and that they can be dated in order to get a more accurate picture of the time scale.

The limitations of coring and pollen diagrams in relation to detecting humans from these time periods is also evident. These people usually had too small an influence on their environment in order to detect them using a pollen diagram and it would require a massive amount of luck to come across their archaeological traces using corings. (Woelders et al., 2016, p. 177) It is clear that definitive proof of Paleolithic and Mesolithic people in the Vrouw Vennepolder will have to come from actual excavations, but given the lack of strong archaeological indications and the unlikelihood of construction taking place it is not likely to happen any time soon.

4.5 Significance of results

The significance of the results of this paper are mainly related to providing a more localized view of the already known bigger picture. The vegetation of the western Netherlands in general was already known, but this research has provided a more detailed look at the two LPAZs of the Vrouw Vennepolder during the Late Pleistocene and Early Holocene. The Vrouw Vennepolder largely follows the same trend as the rest of the western Netherlands but there are some interesting differences here and there that stick out from the larger picture. In particular the hiatus in the Preboreal period and the earlier than expected presences of both *Corylus* and *Alnus*. In relation to dating precise dates may not have been realized but the sampled sequence has been narrowed down to more specific time periods. It appears that the sequence started in the Pleistocene during the Younger Dryas and possibly continued in to the transition from the Younger Dryas to the Holocene Preboreal. After a hiatus in the Preboreal the sequence then continues in the Boreal period and probably ends right at the transition to the Atlantic period. Clear evidence of a Paleolithic or Mesolithic presence in the Vrouw Vennepolder has still not been found. Given the ecological challenges posed by the Vrouw Vennepolder it might not have been possible to build a settlement directly in the Vrouw Vennepolder, but it is clear that the Vrouw Vennepolder would have provided a large amount of resources for potential visitors. The dominant and early presence of *Corylus* could even be a potential sign of humans interacting with the landscape through burning.

5. Conclusion

In conclusion there were two distinct LPAZs present in the sampled sequence from the Vrouw Vennepolder. LPAZ VVP-1 showed a *Pinus* dominated coniferous forest with high amounts of *Corylus* that was slowly starting to transition in to a mixed deciduous forest. The steppe landscape was still present but was also starting to disappear. The river Rhine or one of its tributaries and possibly a lake are likely to have been present in the Vrouw Vennepolder. LPAZ VVP-2 showed the *Corylus* dominated mixed deciduous forest that had started appearing in LPAZ VVP-1 and it also indicated that the steppe was now as good as gone. *Alnus* marshes had appeared and taken a commanding position in the Vrouw Vennepolder. The Rhine or one of its tributaries is likely to have still been in the vicinity. The limitations in the construction of these LPAZs lie mainly with inherent problems of pollen analysis. It is difficult to know which taxa are overrepresented and which are underrepresented in the pollen diagram and it is also difficult to know whether they represent nearby or faraway sources. The varying preservation of different sediments also complicates the matter. In order to get a more accurate picture of the LPAZs it would be useful to sample more areas within the Vrouw Vennepolder in order to be able to compare the different pollen diagrams in the hope of starting to be able to distinguish the local vegetation from the regional and supra-regional vegetation.

The timescale of the sampled sequence has also been narrowed down. It appears the sequence started with LPAZ VVP-1 in the Late Pleistocene during the Younger Dryas and possibly continued in to the transition to the Holocene Preboreal period. After a hiatus in the Preboreal the sequence continued with LPAZ VVP-2 in the Boreal period where it probably ended right at the transition to the Atlantic period. This timescale is based on comparing the sediments and the biostratigraphy to the known geological events and biostratigraphy of the western Netherlands during the Late Pleistocene and Early Holocene. The information provided by comparing the depths of the sediments to the sea-level curve of the Rhine-Meuse delta suggests a shorter and younger sequence that lies mainly in the Atlantic period. However given the difficulty of using the sea-level curve to provide accurate dates, it is better to rely on the information provided by the sediments and the biostratigraphy. The dating of the sampled sequence is limited by the lack of radiocarbon dating which would help provide a more accurate picture of the timescale. Hopefully the bulk samples of peat that were taken from the corings will provide datable macrofossils in order to achieve a better temporal understanding of this sequence.

There is still no definitive evidence for a Paleolithic or Mesolithic human presence in the Vrouw Vennepolder. The ecological challenges that the Vrouw Vennepolder would have posed for humans trying to build a settlement in it are though. The immediate area surrounding the corings would have transitioned from the floodplain of a river to an Alnus marsh and then to a salt marsh. All of which are problematic for building settlements. They could however have built their settlements somewhere else in the Vrouw Vennepolder or outside of it and then used the area for hunting and gathering. The Vrouw Vennepolder would have provided many different kinds of resources like *Corylus* nuts that would be well worth exploiting. The high amounts of *Corylus* in the pollen diagrams could also be an indication of human interaction with the environment through burning but this is far from definitive. The limitations of using coring and palynology to try and prove a human presence in the Late Pleistocene and Early Holocene are vast given the limited archaeological traces they left behind and the almost complete lack of influence they would have had on the environment. In order to prove a Paleolithic or Mesolithic presence in the Vrouw Vennepolder actual excavations will probably have to take place, but given the lack of clear archaeological indicators it is unlikely that this will happen any time soon.

Abstract

In order to reconstruct the vegetation of the Vrouw Vennepolder during the Late Pleistocene and Early Holocene pollen samples were studied under a microscope and the information was then turned in to pollen diagrams. These pollen diagrams showed two distinct local pollen assemblage zones (LPAZ) throughout the sequence. LPAZ VVP-1 showed a *Pinus* dominated coniferous forest with high amounts of *Corylus* that was slowly transitioning into a mixed deciduous forest. The steppe landscape was slowly disappearing and the Rhine or one of its tributaries and possibly a lake were likely nearby. LPAZ VVP-2 showed a now *Corylus* dominated mixed deciduous forest and the likely complete disappearance of the steppe. *Alnus* marshes now also played a dominant role. The river was likely still nearby. These results provide a more detailed picture of the vegetation of the Vrouw Vennepolder.

In order to add a more precise timescale to the sampled sequence the sediments and the biostratigraphy were compared to the geological events and biostratigraphy of the western Netherlands during the Late Pleistocene and Early Holocene. This revealed that the sequence started with LPAZ VVP-1 in the Late Pleistocene during the Younger Dryas and possibly continued in to the transition to the Holocene Preboreal. After a hiatus in the Preboreal the sequence continued with LPAZ VVP-2 in the Boreal period which probably ended at the transition to the Atlantic period. The depths of the sediments were also correlated to the sea-level curve of the Rhine-Meuse delta in order to provide further dating information. This method suggested a much younger and shorter sequence in the Atlantic, but given the difficulties of this method it is better to rely on the information provided by the sediments and the biostratigraphy. These results provide a more detailed timescale for the sampled sequence.

In order to determine the possibility of Paleolithic and Mesolithic groups visiting the Vrouw Vennepolder the Vrouw Vennepolder was analyzed in regards to the resources and the ecological challenges it could provide. The tough ecological challenges it provides in the vicinity of the corings due to wetness mean that it is unlikely that humans built settlements right there. They could have built them elsewhere in the Vrouw Vennepolder or outside of it and then used the area for hunting and foraging. The Vrouw Vennepolder would however have provided a large amount of resources, *Corylus* nuts in particular, meaning that nearby humans are likely to have exploited the area. The early and dominant presence of *Corylus* in the pollen diagrams could be the result of humans interacting with the environment through burning, but it is far from definitive. These results do not provide evidence for human occupation or exploitation of the Vrouw Vennepolder, but exploitation at least seems very likely.

Reference list

Berendsen, H.J.A., & Stouthamer, E. (2000). Late Weichselian and Holocene palaeogeography of the Rhine-Meuse delta, the Netherlands. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 161(3-4), 311-335. DOI: 10.1016/S0031-0182(00)00073-0

Bos, J.A.A., & Urz, R. (2003). Late Glacial and early Holocene environment in the middle Lahn river valley (Hessen, central-west Germany) and the local impact of early Mesolithic people-pollen and macrofossil evidence. *Vegetation History and Archaeobotany*, 12(1), 19-36. DOI: 10.1007/s00334-003-0006-7

Brouwer, M.E. (2011). *Modeling Mesolithic hunter-gatherer land use and post-glacial landscape dynamics in the central Netherlands*. Michigan State University ProQuest Dissertations Publishing.

Cappers, R.T.J., & Neef, R. (2012). *Handbook of plant palaeoecology*. Havertown: Barkhuis.

De Bie, M. & Vermeersch, P.M. (1998). Pleistocene-Holocene transition in Benelux. *Quaternary International*, 49, 29-43. DOI: 10.1016/S1040-6182(97)00052-9

Hijma, M. & Cohen, K.M. (2019). Holocene sea-level database for the Rhine-Meuse Delta, the Netherlands: Implications for the pre-8.2 ka sea-level jump. *Quaternary Science Reviews*, 214, 68-86. DOI: 10.1016/j.quascirev.2019.05.001

Huizer, J., de Jonge, N., van der A, S., & Mulder N.F. (2011). *Archeologische verwachtings-en beleidsadvieskaart voor de gemeente Kaag en Braassem*. ADC Heritage BV.

Mol, J. (2023, June 14). *Diep bodemonderzoek. Wat zit er in de ondergrond van Vrouw Vennepolder? Eerste resultaten Archeologisch Onderzoek Universiteit Leiden*. Land Van Ons. Diep bodemonderzoek – Land van Ons

Rappol, M., & Soonius, C. (1994). *In de bodem van Noord-Holland*. Lingua Terrae.

Van Geel, B., Bohncke, S.J.P., & Dee H. (1980). A Palaeological study of an Upper Late Glacial and Holocene sequence from "De Borchert", the Netherlands. *Review of Palaeobotany and Palynology*, 31, 367-448.

Weeda, E.J. (1985). *Nederlandse oecologische flora: wilde planten en hun relaties. 1*. Amsterdam: IVN.

Weeda, E.J., & Deursen, C.G.M. van. (1987). *Nederlandse oecologische flora: wilde planten en hun relaties. 2*. Amsterdam: IVN.

Weeda, E.J., & Deursen, C.G.M. van. (1988). *Nederlandse oecologische flora: wilde planten en hun relaties. 3*. Amsterdam: IVN.

Weeda, E.J., & Deursen, C.G.M. van. (1991). *Nederlandse oecologische flora: wilde planten en hun relaties. 4*. Amsterdam: IVN.

Weeda, E.J., & Deursen, C.G.M. van. (1994). *Nederlandse oecologische flora: wilde planten en hun relaties. 5*. Amsterdam: IVN.

Woelders, L., Bos, J.A.A., de Kort, J.W., & Hoek W.Z. (2016). Early Holocene environmental change and the presence of Mesolithic people in the Tungelroyse Beek valley near Mildert, the Netherlands. *Vegetation History and Archaeobotany*, 25(2), 177-189. DOI: 10.1007/s00334-015-0543-x