Excursion guide

15TH EUROPEAN HEATHLANDS NETWORK WORKSHOP

Lowland heaths under pressure: *challenges in ecological restoration*

Aug 20 - 25/26 | **2017**

Nijmegen | Dwingeloo | The Netherlands

Excursion guide

15TH EUROPEAN HEATHLANDS NETWORK WORKSHOP

Lowland heaths under pressure: *challenges in ecological restoration*

Aug 20 - 25/26 | **2017**

Nijmegen | Dwingeloo | The Netherlands

Colofon

Excursion guide
European Heathlands Network Workshop 2017
20.08.-26.08.2017 Nijmegen | Dwingeloo |The Netherlands

Authors (in alphabetical order):
Ab Grootjans
Andre Jansen
Leontien Krul
Eva Remke
Jap Smits
Gert-Jan van Duinen
Joost Vogels
Maaike Weijters

Editors:
Ab Grootjans
Eva Remke
Joost Vogels

Design:
Lian Hendrickx, www.lianinline.nl

Photos:
Cover - Jap Smits
Rest excursion guide - mentioned at each foto

Sponsors:
Province of Drenthe
Province of Gelderland
OBN/VBNE

Organizers:
Bargerveen Foundation
Staatsbosbeheer / State Forestry Administration
Radboud University Nijmegen
Unie van Bosgroepen
B-WARE
Research Centre

Site managers:
Hoge Veluwe National Park
Natuurmonumenten
Staatsbosbeheer

Contents

General introduction

A BRIEF HISTORY OF DUTCH HEATHLANDS

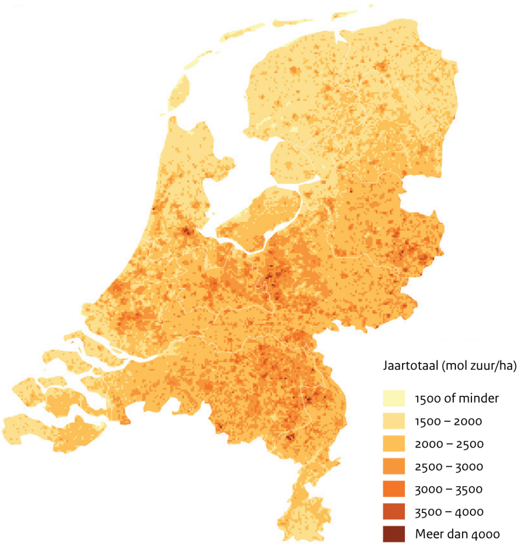
The southern and eastern part of The Netherlands consists mainly of sandy deposits from Pleistocene origin. These sandy deposits are part of the European sand belt, which extends from Britain, through the Netherlands, Belgium, Germany, Denmark and Poland up to the Russian border. These deposits are generally poor in mineral composition. The climate of the Netherlands is classified as temperate oceanic, with generally high levels of precipitation throughout the year. The annual precipitation surplus has led to a general decline in soil fertility through weathering and leaching processes by the slightly acidic rain water. The combination of both characteristics lead to a generally low fertility of soils and to the formation of podzols, are very unsuitable for agriculture. In the past, mankind further influenced the speed of soil impoverishment by using these areas as nutrient source (outfields), with predominant land use practices such as grazing, mowing, sod-cutting, etc. in order to sustain intensive farming practises (mostly grain farming) in the much smaller infields. This resulted ultimately in a landscape with vast areas of dry and wet heathland vegetation, with small farming settlements situated as "islands" inside this heathland landscape. This type of heathland farming was widespread in the region and can also be found in bordering Belgium, Germany, France, Denmark and in somewhat differing forms in Britain, Spain, Portugal and coastal Scandinavia. After the introduction of artificial fertilizer in the 19th century, the necessity of heathlands as nutrient source for the infields ceased to exist, leading to the abandonment of the heathland farming system. Subsequently, large areas of heathland were transformed into farmland. Nowadays, only 20% of the original area of heathlands is still present in the Netherlands, most of which are now part of protected nature reserves.

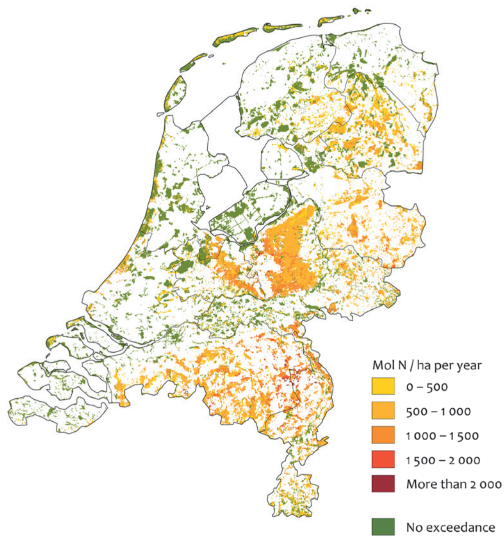
GEOLOGICAL ASPECTS

Dutch heathlands are found in a variety of sandy soils, which in part can be traced back to the periods of glaciations and interglacial periods. During the Saalian glaciation, the Netherlands was partly covered by the Scandinavian ice sheet, covering the upper part of the Netherlands roughly from the lines between Haarlem in the west via Amersfoort and Nijmegen in the east. The ice sheet created large mounds of pushed-up deposits called push moraines, consisting of relatively coarse grained fluviatile deposits of the Rhine and the ancient Eridanos river systems. In subsequent interglacial periods, these glacial mounds have been eroded by fluvioglacial processes and by the rivers Rhine and Maas. Striking examples of glacial mounds that are still very visible in the landscape are the *Utrechtse heuvelrug*, the *Veluwe massief*, *Sallandse heuvelrug* and the glacial mound of *Nijmegen*. Further up north, most prominently in the province of Drenthe, the Saalian ice sheath deposited a layer of boulder clay; a mixture of ice-eroded material consisting of loamy particles intermixed with small gravel, which plays an important role in understanding the often complex hydrology of the wet heathlands and heathland bog systems present here.

During the Weichselian glaciation period, large parts of the North Sea basin and the Netherlands were part of a so-called polar desert, a very dry and cold region with strong winds. These winds led to the deposition of large quantities of sand throughout the country, leaving a several metres thick layer of cover sand in the lower parts of the Netherlands. Cover sands make up

• **Fig 1** • *Overview photos of three different heathlands on differing deposits.* Top: *dry heathland on push moraine at Heumense Schans.* Middle: *Dwingelderveld wet Ericion tetralicis heathland.* Bottom: *ombrotrophic pools in heathland at Hatertse Vennen.* - Photos: Jap Smits.





• Fig 2 • Left: *Total annual load of acidifying compounds in the Netherlands (Mol/ha/year) in 2015. Note the higher deposition in the southern and eastern part of the Netherlands, in the sandy region in the Netherlands.* - Source: RIVM, 2016. Online available at: http://www.clo.nl/sites/default/files infographics/0184_002k_clo_16_nl.png.

• Fig 3 • Right: *Critical Nitrogen load exceedance in Dutch Nature areas in 2009. Note that the empirical critical load for dry heathland vegetation is estimated at 1070 Mol/Ha/year, and that deposition levels of N have been roughly 1.5 times higher in the past. Annually, the Critical load exceedance is 0.3 to more than 1 times the critical load for Dutch heathland vegetation.* - Source: PBL, GCN. Online available at http://www.clo.nl/sites/default/files/infographics/1423_002k_clo_01_en.jpg

large parts of the Pleistocene region, and are most prevalent in the Southern part of the Netherlands below the river Maas, also in the eastern part. Near the push moraines, the layer of cover sand is often discontinuous. The river Maas also transported large quantities of relative fine-grained sand which consolidated in the south-eastern part of the Netherlands. This sand was subsequently wind-blown to form a long stretch of relatively large river dunes bordering the river Maas to the east.

All of the above-mentioned sandy deposits are home to heathland systems, and are often quite informative about the ecology and differences between ecological aspects of the heathlands. The excursion programme is set up to with the idea in mind to visit heathlands situated on differing deposits, so that the participants get a good impression of the natural diversity of our heathlands (Fig 1).

THREATS

The first major threats to heathland biodiversity and species persistence were large scaled land reclamation projects and subsequent loss of habitat, as well as loss of management, leading to afforestation of heathland remnants. Those problems are nowadays however not of major concern. Most of the remaining heathland remnants are highly protected nature reserves which are being intensively managed in order to preserve the open character. One of the current major threats are the indirect effects of land reclamation projects, which often have led to habitat fragmentation and severe desiccation of wet heathland and accompanying habitat types such as wet heath, ombrotrophic pools and heathland bog systems.

Another major threat that resulted from the intensification of agriculture and accompanying industrialization is the highly increased emission and subsequent deposition of eutrophying and acidifying compounds through the air. The annual deposition of acidifying compounds peaked in the 80's in the past century and could reach levels as high as 80 Kg/ha/year (natural background deposition in The Netherlands is estimated at 5-10 Kg/ha/year). Currently, emissions of SO_X, NO_X and NH_Y have dropped due to environmental legislation, but the annual deposition of acidifying and eutrophying compounds is still in extreme exceedance of the empirically derived critical loads for dry heathland (H4030) and accompanying habitat types (see Fig 2 and 3).

Not surprisingly, acidification and eutrophication has a major impact on species persistence and biodiversity of Dutch heathlands and challenges managers and scientists in the Netherlands to devise novel and unconventional measures aimed at restoring and/or mitigating the effects of air pollution. This will be undoubtedly an important and often reoccurring issue during the field excursions and presentations. Another major topic in Dutch nature conservation and restoration efforts is to reduce the effects of habitat fragmentation and dessication. In the Netherlands, there are several large-scaled nature restoration projects that aim to restore heathlands at the landscape level. During the excursions, we will also focus much attention to this aspect of nature conservation, in visiting two large-scaled nature restoration projects at Dwingelderveld and Bargerveen.

Excursion programme

ON TRANSPORTATION AND CLOTHING

Walks will mostly stretching a distance of roughly 3-5 km; longer distances will be covered by bike within the field sites. We will also visit wet parts (especially Wednesday afternoon), bring appropriate boots for these excursions if you want to visit all stops without getting your feet wet.

Important: If you are unable to walk of bike long distances, please inform the organizing committee beforehand, so we can arrange alternative means of travel.

EMERGENCY CALLS:

If you get somehow lost during the excursion, please make a call to one of the following numbers:

Joost Vogels: +31(0)647 280 685

Eva Remke: + 31 (0)647 280 737

SUNDAY EVENING | AUGUST 20 MOOKERHEIDE

What: Walking excursion from the hotel to the nearby Mookerheide and Heumense Schans.

Departure place: Hotel Molenhoek

Departure time: 19:30

End of excursion: 21:00

TUESDAY AFTERNOON | AUGUST 22 HATERTSE VENNEN

What: Bus and walking Excursion to the Hatertse Vennen heathland and moorland pool area.

Departure place: University of Nijmegen.

Departure time: 13:00, lunch inside the bus and start of field excursion

Estimated end of excursion: 18:30

Important: bring your field clothes and other equipment from the morning departure from the hotel to the university lectures. We will NOT return to the hotel between lectures and excursion.

WEDNESDAY | AUGUST 23

What: Full excursion and relocation day by bus. Check out from Hotel Molenhoek and evening check-in at Hotel de Borken, including two excursion stops, The Hoge Veluwe National Park and Stroothuizen.

THE HOGE VELUWE NATIONAL PARK

Bus excursion to the park. Bike excursion inside the park.

Departure place: Hotel Molenhoek

Departure time: 8:00

Estimated arrival: 8:45

End and depart to Stroothuizen: 14:00

Important: this will be a long bike excursion. If you are unable to travel long distances by bike, inform the organizing committee, we will arrange alternative transport inside the park.

STROOTHUIZEN WET CIRCIO-MOLINIETUM HEATHLAND

Walking excursion through the area.

Arrival: 15:30

End of excursion *and depart to Hotel de Borken:* 17:00

Arrival at Hotel de Borken: 18:30

Bring appropriate footwear (Boots or water tight boots)

THURSDAY AFTERNOON | AUGUST 24
DWINGELDERVELD/NOORDENVELD

What: Bike and walking excursion to the Dwingelderveld and Noordenveld heathland restoration site. At the end of the excursion we will bring a visit to the Dwingelderveld Radio telescope.
Departure place: Landhotel de Borken
Departure time: 13:00h by bike (3 km bike route)
Arrival at first excursion stop: 13:30
End of field excursion: 16:30
Visit Radio Telescope: 16:30 - 17:30
Depart to Hotel De Borken: 17:30
Important: if you are unable to travel by bike, inform the organizing committee, we will arrange alternative transport inside the park.

FRIDAY AFTERNOON | AUGUST 25
BARGERVEEN | PLUS PROGRAMME

What: Bus and walking excursion to Bargerveen ombrotrophic bog reserve. This excursion is part of the plus programme and only applies to participants that singed up for the plus programme.
Departure place: Hotel de Borken
Departure time: 13:30 by bus
Arrival at Bargerveen: 14:15
End of field excursion: 17:30
Arrival at Hotel de Borken: 18:15

• **Fig 1** • *Location of all excursion sites. Note that the Bargerveen excursion is part of the plus programme.*

1 Mooker Heide | Heumense Schans

Sunday evening, 20th of August

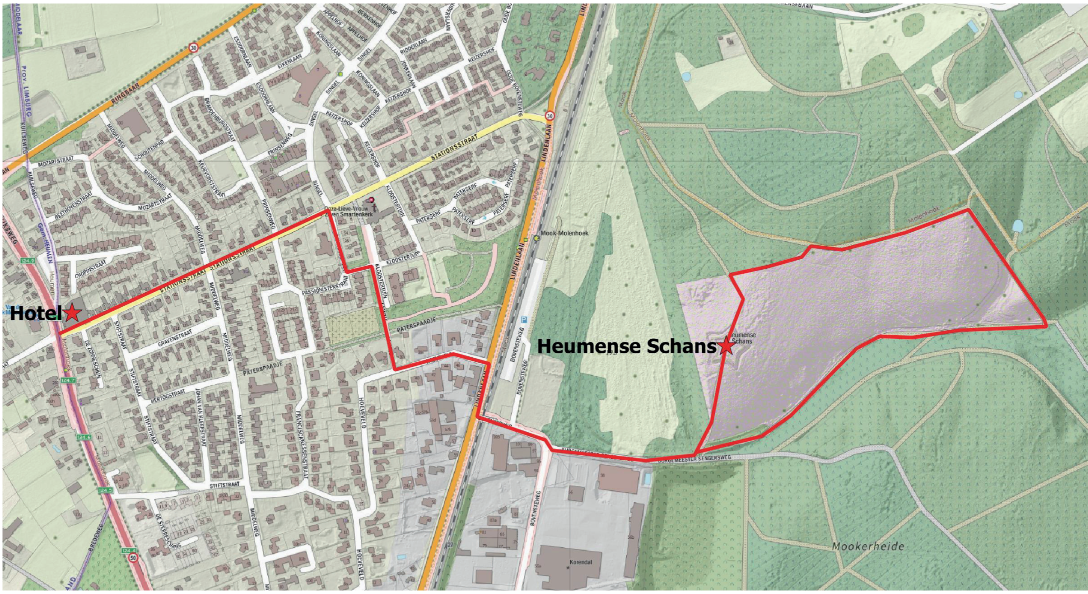
SITE CHARACTERISTICS

The area is a heathland relic is located at the intersection of an end moraine to outwash fan of the Saalian ice age (380.000-130.000 years BP, see Fig 5). The total area of these heathlands are ca. 235 ha. The excursion leads along a five-pointed star fort of 50 meters in diameter (see Fig 1). It is a relic from the second half of the 17th century and probably constructed by the army of William III and lies roughly 50 meters above sea level. The area is also known from the Battle of Mookerheide (1574) during the 80 years Dutch independence war (from Spain), when more than 3,000 people died.

• ***Ecological qualities***

A total of 77 species of breeding birds have been recorded in the area. Many typical open heathland species occur here: European Nightjar (*Caprimulgus europaeus*), Long-eared Owl (*Asio otus*), Green Woodpecker (*Picus viridis*), European Stonechat (*Saxicola rubicola*), Yellowhammer (*Emberiza citrinella*), and Common Linnet (*Linaria cannabina*). The Eurasian Skylark (*Alauda arvensis*) is still occurring at the Heumense Schans, but its population is decreasing. For reptiles, the Smooth Snake (*Coronella austriaca*), Sand Lizard (*Lacerta agilis*) (see Fig 3) and Slowworm (*Anguis fragilis*) are worthwhile mentioning. Grasshoppers species, such as Saddle-backed Bush Cricket (*Ephippiger diurnus*) (see Fig 4) and Blue-winged Grasshopper (*Oedipoda caerulescens*) (see Fig 6), both rare in The Netherlands, have stable populations in this area.

• **Fig 1** • *Aerial photograph of the five star fort at Heumen, the “Heumense schans”.* - Google earth.



• **Fig 2** • *Route of the evening walk along the "Heumense Schans" .*

MANAGEMENT AND MANAGEMENT CHALLENGES

In recent years, a consortium of different organisations (under the name 'Heiderijk Nijmegen Mook') joined forces to restore former heathlands. Partners within the consortium are Natuurmonumenten, State Forestry Services, Municipality of Nijmegen and ProRail. Part of the forests between Nijmegen and Mook have been gradually transformed into a more open and diverse landscape. Existing heathlands have been enlarged and interconnected by corridors. Partly, areas have still to be transformed, for instance at the Mulderskop-Heumense Schans.

The purpose of the Heiderijk project was to restore a part of the historical landscape of Nijmegen. Especially to the south of the city extensive heathlands were present in the past. Open heathland once stretched from Heumensoord to the Mookerheide. However, much of the heath has disappeared due to large-scaled afforestation during the last century. The remaining heathland consisted of many small and isolated patches, which often were increasingly encroached by shrubs and trees. This had a detrimental effect of the typical open landscape and dry heathland species.

DAY PROGRAMME

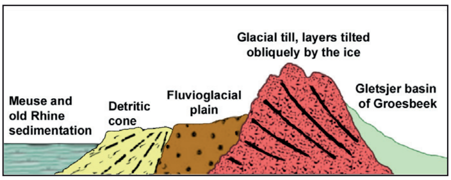
- On Sunday evening there will be an evening walk of 3.5-4 km to the "Heumensche Schans" on the Mooker Heath (see Fig 2). This evening walk is an optional and informal excursion and will

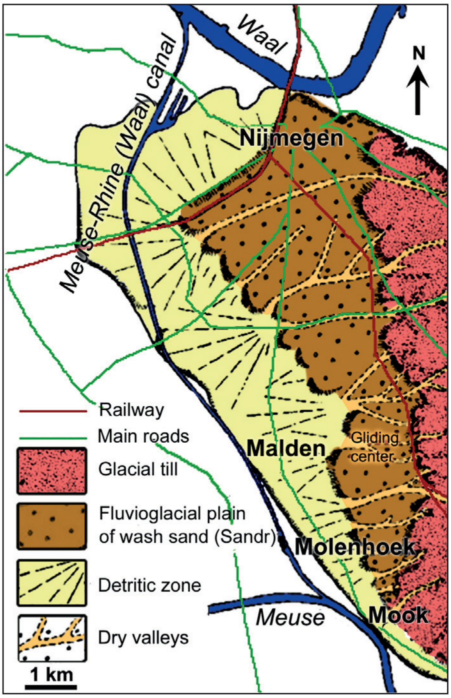
• **Fig 3** • *Sand Lizard (Lacerta agilis).* - Photo: R. Krekels.

• **Fig 4** • *Saddle-backed Bush Cricket (Ephippiger diurnus).* - Photo: R. Krekels.

be led by Jap Smits (State Forestry Services, forester ecology). If you want to take part, please be at the main entrance of the hotel at 19:30.

Authors: Jap Smits & Eva Remke





• **Fig 5** • *Overview of the geology of the larger area – two graphics I & II.*
Taken with permission from Teunissen & Pierson - Radboud University Nijmegen: www.vcbio.science.ru.nl/eng

FURTHER INFORMATION/ FURTHER READING

Internet:

- http://www.vcbio.science.ru.nl/virtuallessons/landscape/heumensoordgeo/
- https://www.natuurmonumenten.nl/natuurgebied/mookerheide/heiderijk

• **Fig 6** • *Blue-winged Grasshopper (Oedipoda caerulescens).* - Photo: R. Krekels.

2 Hatertse Vennen

Tuesday afternoon, 22nd of August

SITE CHARACTERISTICS

The Haterste Vennen are situated in an old drift sand area along the river Maas, containing ca. 30 open moorland pools. These pools are situated within forests, heathlands and also in small-scaled agricultural landscape. The area of 479 ha is managed by the State Forestry Services since 1980. The area is highly characteristic due to the stark contrast between particularly dry heathland ecosystems on ancient river dunes and very wet ecosystems in the bordering lower parts, with locally initial bog vegetation development.

• *Geology*

The geology of the area is quite complex. Ancient river deposits of the Rhine and Maas are dominant in deeper layers. During the Saalian glacial period the land ice reached Nijmegen. A part of the river deposits were pushed together and formed the push morene at Nijmegen (see Fig 1 and 2). During the last glacial period, the Weichselian glaciation, side arms of the rivers Rhine and Maas ran through the area. These river systems deposited coarse sand and gravel. At the start of the Holocene the rivers changed their course again and left a one meter thick layer of clay on top of the coarse sandy base. Later in the Holocene, fine aeolian sands from the Maas river system reached the area from the west. A thick drift sand area developed on top of the clay layer. In old river beds, which were not covered with drift sand, mires and open surface waters could establish. One example is "Het Wijchens Ven". In a later, warmer and drier period, the open and not densely vegetated dunes further dried out. As a consequence, deep dune deflation areas and high dune ridges could develop. At some places the deflation flats were eroded close to the river clay deposits. This dry period was followed by a much wetter period. The low lying deflation areas were again flooded creating relatively large lakes.

• *Hydrology & Soil*

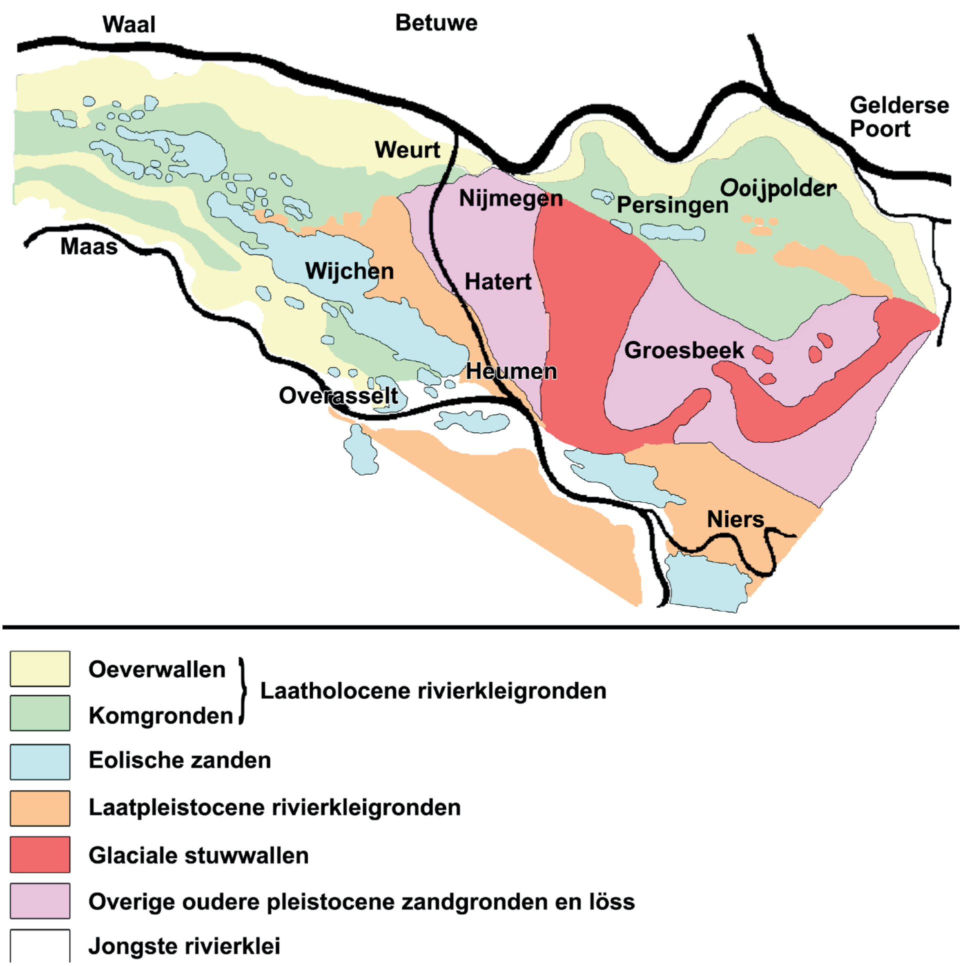
The whole drift sand area has its own local hydrological system due to the highly permeable sandy dunes on top and the thick, nearly impermeable clay layer below (see Fig 2). The water levels in the pools are generally much higher than the groundwater level in the surrounding. This is caused by highly impervious organic layers at the base of the pools, which have been formed by deposition of dispersed humus originating from incomplete decomposition of plant remains. These layers prevent rapid infiltration of water to deeper layers. The water levels in the dune area are thus generally lower than water levels in the pools. They are controlled by the amount of precipitation and by the thickness of the clay layers. The dunes have a convex shaped groundwater table and this is also true for the area as a whole.

Under the clay layer another aquifer exits, which contains regional ground water. This is fed by surface water from the river Maas and Maas-Waal channel. The water level in the aquifer also follows the levels of the river and the channel.

The ecotones between the dry and wet areas are quite short, because of the lower ground water layer around the dunes than within the pools and the effectively draining, aeolian sands.

Translation Dutch

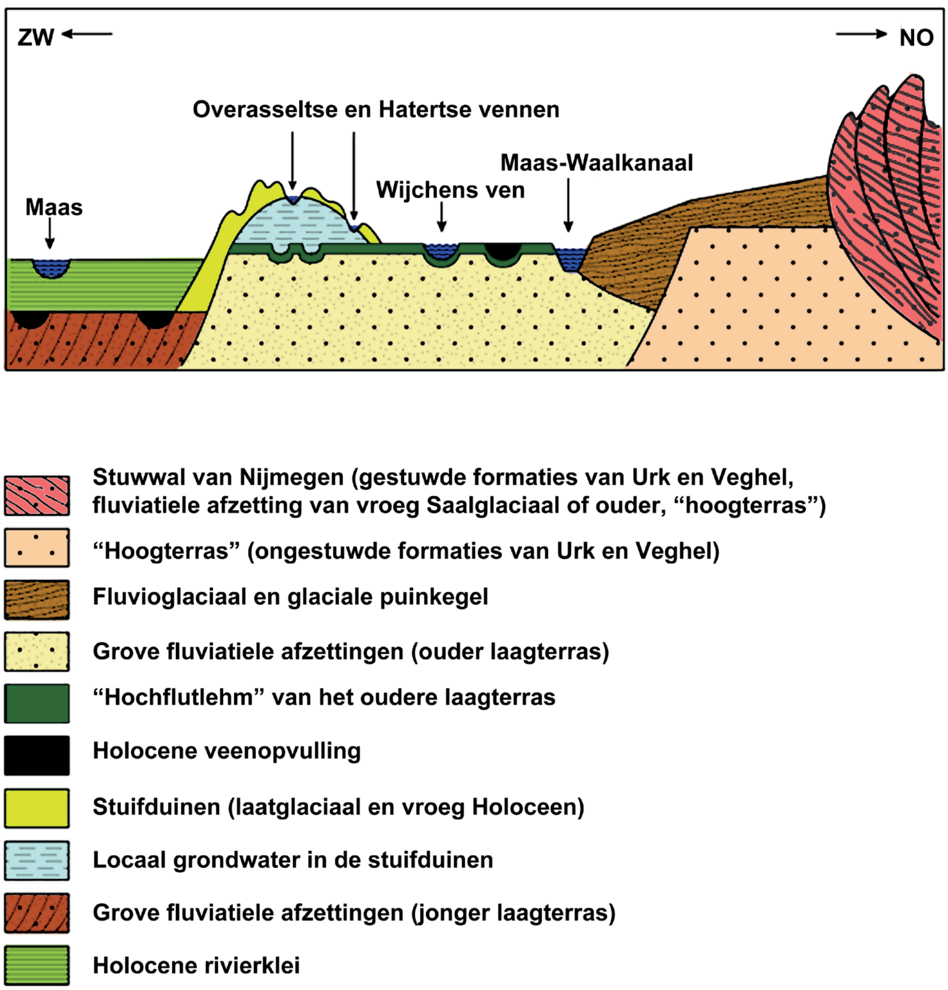
- *Oeverwallen – elevated river bank as ridge alongside rivers*
- *Komgronden – deflations in flood plains with fine clay deposits*
- *Laat holocene rivierkleigronden – late Holocene river clay grounds*
- *Eolische zanden – aeolian sands*
- *Laatpleistocene rivierkleigronden – late Pleistocene river clay grounds*
- *Glaciale stuwwallen – glacial push moraines*
- *Overige oudere pleistocene zandgronden en löss – other old Pleistocene sands and loess*
- *Jongste rivier klei – youngest river clay*



• **Fig 1** • *Geological formations of the Overasseltse and Hatertse Vennen.* - Taken with permission from Teunissen & Pierson - Radboud University Nijmegen: www.vcbio.science.ru.nl/eng

***Translation Dutch** (see also Fig 1 for additional translations):*

- *Fluvioglaciaal en glaciale puinkegel – fluvio-glacial and glacial rock waste cone*
- *Grove fluviatiele afzettingen – coarse fluvial deposits*
- *Laag-/ hoogterras – low/ high terrace*
- *Hochflutlehm – high flood clay deposit of the rivers*
- *Veenopvulling – filling with peat*
- *Stuifduin – shifting dune*
- *Locaal grondwater – local groundwater*



• **Fig 2** • *Lateral section through the Hatertse Vennen.* - Taken with permission from Teunissen & Pierson - Radboud University Nijmegen: www.vcbio.science.ru.nl/eng

• **Fig 3** • *Bog Asphodel (Narthecium ossifragum.* - Photo: Jap Smits.

• **Fig 4** • *Small Cranberry (Vaccinium oxycoxxus) with Spagnum magellanicum.* - Photo: Jap Smits.

The soil and water in most of the area is originally very poor in minerals and nutrients. At present, agricultural land use negatively affects the water composition in parts of the Hatertse Vennen, problems are mainly linked to eutrophication.

• *Land use history*

The archeological, cultural and historical values of the area are high. There many burial sites from the Neolithic Age (2850-200 BC), Bronze Age (2000-1800 BC) and from the Early Iron Age (800-500 BC), which usually consist of small burial mounds.

At the start of the 20th century the area consisted of a mosaic of heathlands, dry grasslands, wetlands, pools, small fens and a few places with coppice wood. A few small settlements with meadows and woods were situated at the outer ranges of the area. Around 1910, ditches were dug at various sites, while during the period 1921-1927 the Maas-Waal channel was constructed. This led to a severe drop in water levels in the area. On top of this, the area has been afforested with coniferous trees for the mining industry: Japanese Larch (*Larix kaempferi*) in the drained pools and Scots Pine (*Pinus sylvestris*) in dry dunes. Locally, the clay layer has been removed to support conifer growth. Furthermore, wet heaths and pools were destroyed in order to create agricultural land. Many pools were partly or completely filled with sand from surrounding dunes. In this way new grasslands for agricultural use have been created, mainly around and close by pools. Due to this, many pools changed in size or vanished completely. Additionally, agricultural land use (mainly arable fields) expanded in the whole area, leading to highly elevated nutrient inputs in the oligotrophic pools.

• *Ecological qualities*

Around the pools and within the wet heath a few special plants can be found: *Narthecium ossifragum* (see Fig 3), *Vaccinium oxycoccus, Sphagnum magellanicum* (see Fig 4), *Hypericum elodes, Dactylorhiza maculata ssp. maculata* and *Andromeda polifolia*. Furthermore, the pools are known for their variety of dragonflies and butterflies such as e.g. the Silver- studded Blue (*Plebejus argus*). An important population of the Viviparous Lizard (*Zootoca vivipara*) exists, but this population is under threat during the last years. The pools harbor also

• **Fig 5** • *Pool 'Uiversnest'.* - Photo: M. Lucas.

threatened amphibians, like the Common Eurasian Spadefoot (*Pelobates fuscus*) and the Northern Crested Newt (*Triturus cristatus*). In the drier habitats, two grasshoppers are worth mentioning: the Wart-biter (*Decticus verrucivorrus*) and *Chorthippus vagans*. Both species are nowadays very rare: Wart-Biter populations in The Netherlands declined to currently two known populations at National Park Hoge Veluwe and Hatertse Vennen, Chorthippus vagans is only known from the Nijmegen area and can only be found at Heumensoord and the Hatertse Vennen. These two species need a highly structured heathland vegetation with much open spaces and, for Wart-biter, the presence of extensively managed arable fields is another important precondition. Another prominent species of the area is the Badger (*Meles meles*).

MANAGEMENT AND MANAGEMENT CHALLENGES

• *Challenges*

Since begin of the last century the whole area has been used for growing coniferous wood for the mining industry. This has had a very negative impact on the local hydrology. The creation of the Maas-Waal channel as well as internal drainage by construction of many ditches further impacted the local hydrology. One of the important restoration measures carried out is therefore the transformation of conifer forest into deciduous woodland and open heathland. State forestry services started with this in 2007. An example of the taken measures will be seen at the excursion stop "Uiversnest" (see Fig 5).

• *Management measures*

Around the pools the conifers have been felled, in order to reduce evapo-transpiration by the vegetaion, and thus increase the supply of rainwater to the local groundwater table. The ground water levels around the pools would rise and leakage of pool water to the groundwater diminish.
Every year, 10% of the vegetation in the immediate surroundings of the pools is mown to prevent shrubs and tree establishment. Thereby, the accumulation of litter is diminished. Pools with terrestrialising bog vegetation are now excluded from sheep grazing and are mown manually (about 0.5 ha).
State Forestry Services also manages ca. 17 ha of cereal crops near the Overasseltse- and Hatertse Vennen (see Fig 6). Here, the last stable population of the Wart-biter of the Netherlands exists. The fields should serve as a reserve for rare plants typical for traditional and extensively managed cereal fields and should also preserve the Wart-biter. The Common Eurasian Spadefoot is another rare species which uses these fields. Winter Rye and Oat are sown in the field in spring (ca. 60-70 kg/ ha). Ploughing, sowing and harvesting is adjusted to the ecological requirement of target species. Per arable field no more than 5 tonnes of manure are added.
The dry and wet heath and the recently deforested areas are grazed by sheep (ca. 56 ha) and partly by Scottish Highland cattle. A hired sheep flock (ca. 250 animals) is grazing the area roughly seven months per year. The shepherd is responsible for the result: a short grazed vegetation without shrub encroachment. If necessary, State Forestry Services removes Seedlings man-

• **Fig 6** • *Small-scaled and extensively managed arable fields.* - Photo: R. Krekels.

ually. The dry heaths are more intensively grazed in order to create sufficient habitat for *Chorthippus vagans.*

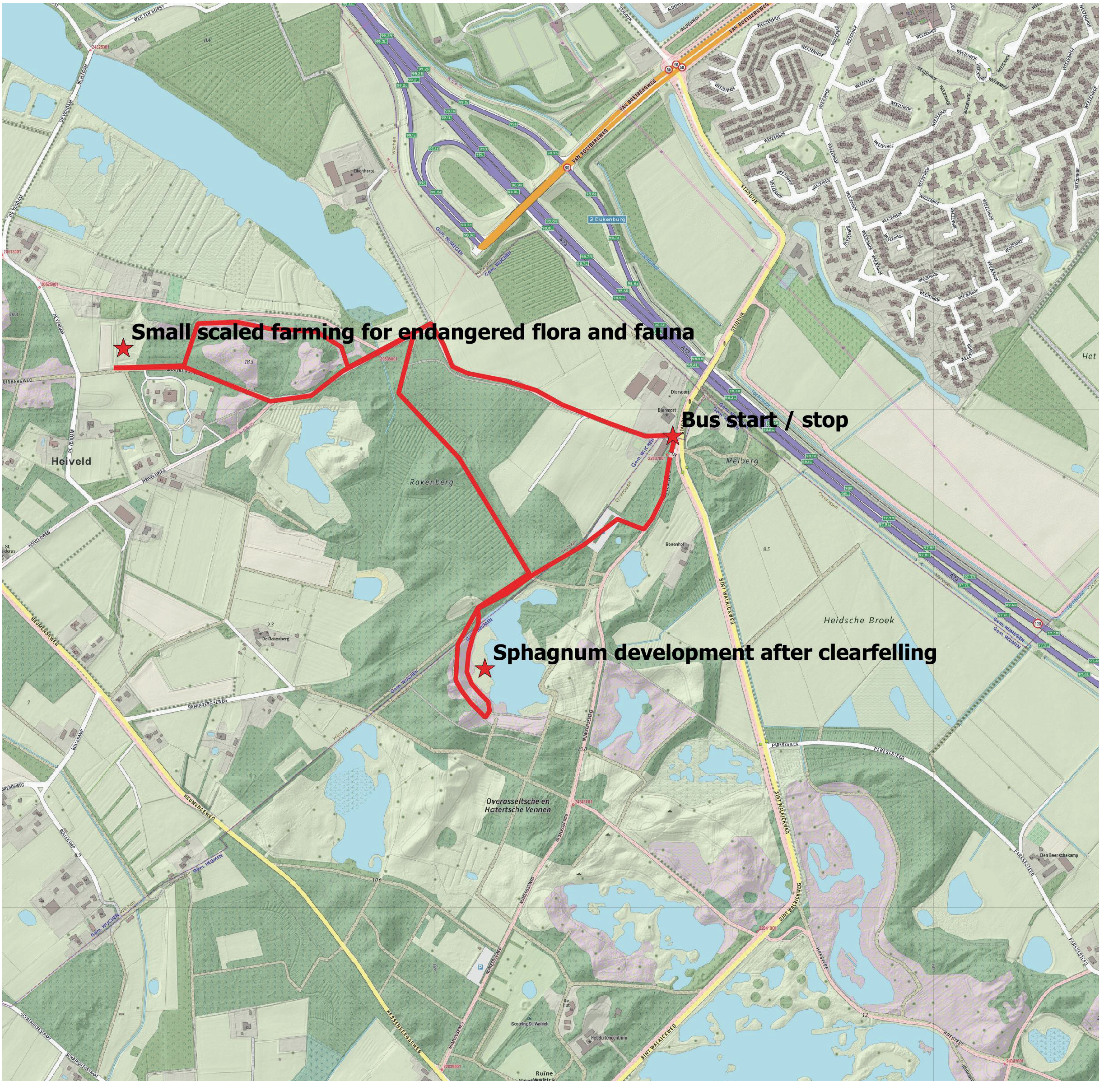
DAY PROGRAMME

- The excursion consists of a walk of ca. 3 km through the forests, heathlands and along the pools and fens of the Hatertse Vennen (see Fig 7). It will take roughly 2,5 hours (start at 14:00, end ca. 16:30). You will be guided by Jap Smits and Harry Woesthuis (State Forestry Service, foresters ecology). We will have two longer stops. One at "Uiversnest" where the development of fens and restoration of the pool "Uiversnest" are explained. The second stop is at the extensive agricultural fields. Here, the small-scaled management of the grain fields and their adjacent ecosystems are shown.

Authors: Jap Smits & Eva Remke

FURTHER INFORMATION/ FURTHER READING

- Buddingh, K., Harsveld, A. & M. Wenker (2010) Overasseltse en Hatertse Vennen: Visie en inrichtingsplan. Dienst Landelijk Gebied regio Oost.
- B-WARE (2008) Ecologisch bodemonderzoek Hatertsche en Overasseltsche Vennen. Nijmegen.
- College van Dijkgraf en Heemraden (2010) Gebiedsplan Hatertsche en Overasseltsche Vennen - Maatwerkplan Stuurgroep Hatertse en Overasseltse Vennen. Waterschap Rivierenland.
- R.F.M. & P.H. van Hoof (2004) De wrattenbijter in de Overasseitse en Hatertse vennen. Monitoring 2004. Bureau Natuurbalans - Limes Divergens en EIS-Nederland, Nijmegen.
- Smeding, F., & H. Woesthuis (2011) Monitoringplan Vennen, Evaluatiecriteria vernattingsmaatregelen vennengebieden. Staatsbosbeheer.



• **Fig 7** • *Excursion route with two stops.*

- Smeding, F., Folsche. E. & H. Woesthuis (2011) Beheerplan Vennengebied. Staatsbosbeheer.

Internet:

- http://www.bomengids.nl/vennendocs/Visie_en_inrichtingsplan_Overasseltse_en%20Hatertse_Vennen.pdf
- http://www.vcbio.science.ru.nl/virtuallessons/landscape/hatertsevengeo/

3 The Hoge Veluwe National Park

Wednesday morning, 23rd of August

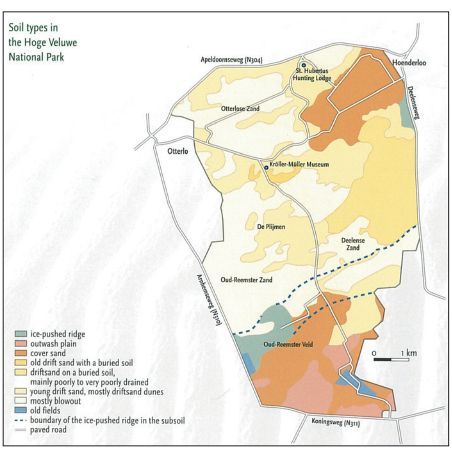
SITE CHARACTERISTICS

• *Origin*

The Hoge Veluwe National Park is one of the oldest and largest national parks in the Netherlands (covering 5400 ha). It was founded in 1935 when the landowners Anton Kröller and Helene Kröller-Müller were forced to sell their estate to a foundation (Foundation The Hoge Veluwe Park) and their art collection to the Dutch government. This Foundation has since been responsible for the management of the estate. The art collection is now displayed in the Kröller-Müller Museum, which is situated inside the Park.

• *Geology and geogenesis*

The area is rich in soil types and soil features which are helpful in understanding the ecological qualities of the area (Fig 1).



• **Fig 1** • *Geological situation of the National park.* - Taken with permission from Beukenhof (red) et al., 2007.

The Park is situated on the western flank of the Veluwe "massif", one of the largest push moraines of Europe, created by the Scandinavian ice sheet in the Saalian glaciation period. Riverine deposits from precursors of the Rhine and the ancient Eridanos river system were pushed upwards by the advancing ice sheath, forming large hills consisting mainly of sand and gravel, intermixed with loam and small sheets of boulder clay. During the following Weichselian glaciaton, periods of extremely cold and dry climatic conditions occurred in the Netherlands, resulting in the formation of a cold polar desert. Polar winds transported large amounts of sand and loess from this desert, which were redeposited in the area as cover sands. In recent history (1000 BP), man-induced large-scaled remobilization of these cover sands further shaping the current soil surface and soil processes.

The top soil of the Northwestern part of the Park consists of a layer of cover sand of several meters thick. Here, large areas have been transformed into large drift sands from over-exploitation by man in the 14th and 15th century. In this area, large areas are still characterized by drift sand and accompanying plant communities in all stages of succession (Fig 2).

To the south, the push moraine of "Oud Reemst" can be found at the surface or subsurface. At several sites, the soil is relatively loam and/or mineral rich, leading to a more frequent occurrence of dry *Nardogalion* communities in this part of the Park. Further south, the soil consists of a mixture

• **Fig 2** • *Large areas of drift sand, psammophilic heathland intermixed with Pinus seedlings characterize the drift sand landscape in the Western side of the National Park.* - Photo: Jap Smits.

of gravel, loam and sand, and is part of a larger Sandr terrace, filling the area between the push moraines up to the river Rhine. In the areas with a layer of cover sand present, *Calluna vulgaris* dominated dry heath is the predominant vegetation. In the coarser, but also loam richer soils of the Sandr terrace, large areas are nowadays dominated by purple moorgrass (*Molinia caerulea*).

The eastern part of the National Park is flanking the push moraine of the Veluwe. Surprisingly, this is also by far the wettest part of the park. The reason for these extraordinary wet conditions here are the widespread occurrence of so-called placic horizons (Fig 3, see also Jansen et al, 2014). These are concretions of solid ferrous oxides which form an impermeable layer for both infiltration and seepage water, which typically develop at the boundary between fine grained sand particles and coarser grained sand and gravel. In this region, the layer of cover sand above the coarser grained material of glacial origin is relatively thin, creating ideal conditions for the formation of these impermeable iron pans.

• **Fig 3** • Above: *The IJzeren man, a wet heathland and heathland spring inside the park.* Below: *placic horizons are responsible for the extreme wet conditions in this part of the park.* - Photo: Andre Jansen.

• ***Farmland and cottages***

Inside the Park, several small settlements are present as "agricultural islands" in the area, dating back to at least the 14th century. In a later period, the influence of several so-called *cottiers* is also noteworthy. Those were poor farmers, who tried to create arable land in the heathlands during the final stage of the heathland farming era (1800-1900). The nearby settlement of Hoenderloo originates from this period. The area bordering this settlement is therefore highly influenced by farming activities. Also, several small (former) arable fields are present inside the area as well as fields created for game hunting. Many of the arable fields are nowadays refuge for several highly endangered plant species of arable fields and important in providing supplementary food for birds and reptiles.

• ***The second world war***

Another major event shaping the ecological qualities of the reserve is the Second World War. During this period, German occupying forces confiscated large areas of the National Park in order to create an airfield. Landing strips, taxi lanes, fuel bunkers, hangars and a network of trenches were created. After the war, these were mostly destroyed by allied forces, but remnants of concrete and other building material are still present in the soil. Base cations released from this material, as well as the disturbance of the top soil resulted in a higher base cation release and subsequently, higher buffering to soil acidification.

• ***Ecological qualities***

As a result of the occurrence and interplay between these soil types, its geological features and early and distant history, the area is home to a rich and diverse flora and fauna. In the northwestern part, there are still large areas of lichen-steppes and psammophilic heathlands present, which are notably rich in lichen species, reptiles and several inverterbrate species. Grayling (*Hipparchia semele)*, Silver-spotted Skipper (*Hesperia comma)*, Wart-biter (*Decticus verrucivorus)* and Blue-winged Grasshopper (*Oedipoda caerulescens)* are species that can be typically found in these warm and dry conditions. Further to the east at the Deelense Veld where placic horizons in the subsoil resulted in development of wet heath, acid and weakly buffered moorland pools and sphagnum communities, *Gentiana pneumontanthe, Narthecium ossifragum, Sphagnum molle, Juncus acutiflorus* are some of the endangered and/or characteristic plant species. The butterfly species Alcon Blue (*Phengaris alcon)* and Silver-studded Blue (*Plebeius)* are characteristic butterfly species with populations typically found in this part of the park. The moorland pools harbour characteristic dragonfly species Crescent Bluet (*Coenagrion lunulatum)*, Large White-faced Darter (*Leucorrhinia pectoralis)* and Moorland Hawker (*Aeschna juncea)*, amongst others.

In the former air-field, a high number of endangered plant and animal species that require weakly buffered soil conditions are still present. *Carex ericetorum*, *Botrichia lunaria* and *Schorzonera humilis* are highly endangered plant species and typically

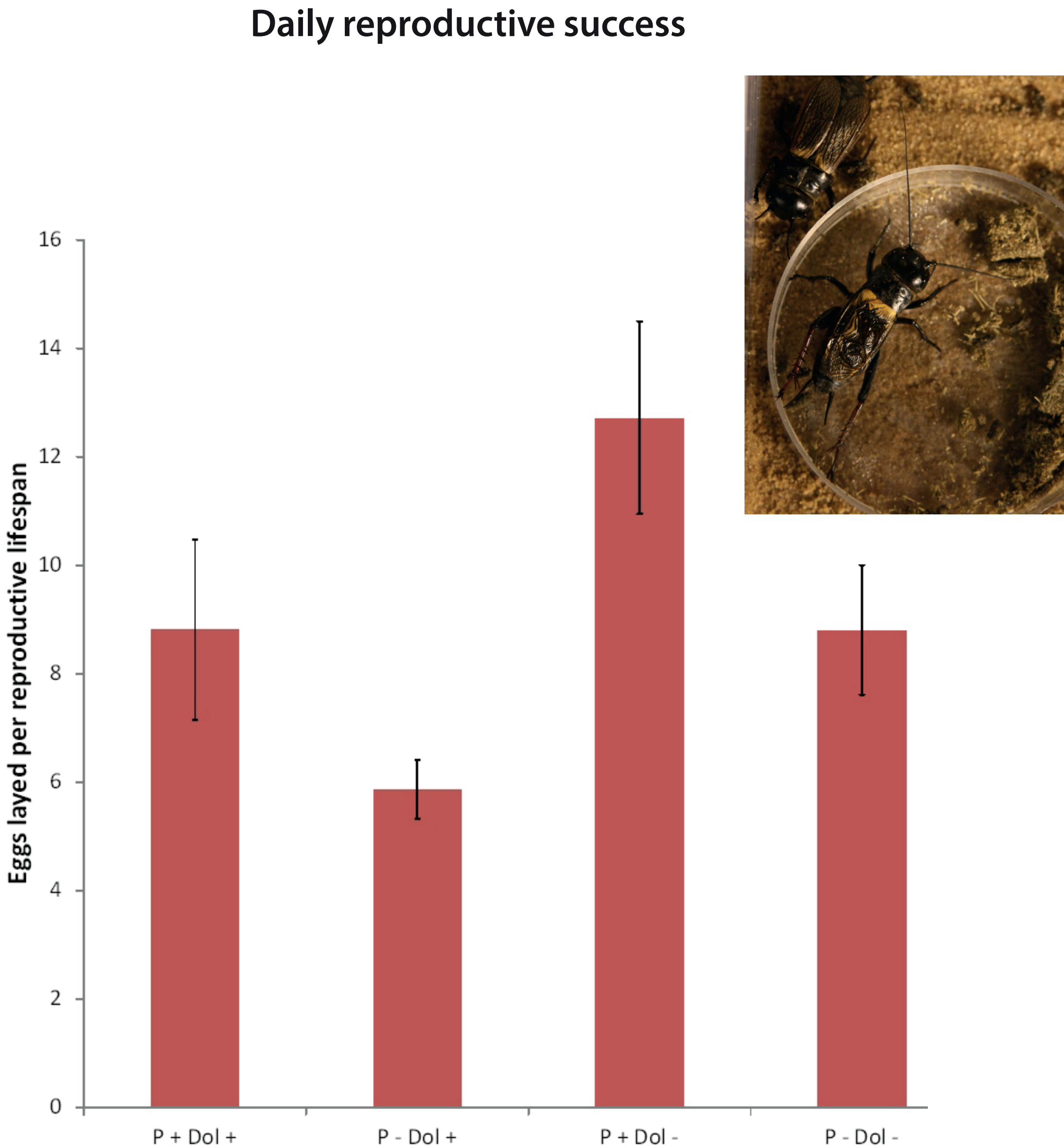
• **Fig 4** • *The Ladybird spider (Eresus sandaliatus) can be found everywhere in the park when there is sufficient open and dry vegetation. Highest densities of individuals are however to be found in the open Nardo-galion communities at Braamsveldje.* - Photo: Jap Smits.

found near former taxi lanes. Endangered butterflies such as Grizzled Skipper (*Pyrgus malvae)*, Dark Green Fritillary (*Argynnis aglaja)* and Sooty Copper (*Lycaena tityrus)* are profiting from the influence of German activities as well, due to a higher occurrence of host plants, increased host plant quality and/or increased nectar availability. An extremely high density of living tubes (up to 25 per square meter) of the highly characteristic Purseweb Spider (*Atypus affinis)* is highly suggestive of a high abundance and activity of soil dwelling arthropods as well. Another characteristic spider similar in feeding strategy is the beautifully colored Ladybird Spider (*Eresus sandaliatus)* (Fig 4), which can also be found in high densities in this area. Recently, a population of the small grasshopper species *Tetrix bipunctata*, long thought to be extinct in the Netherlands, was rediscovered in this area.

MANAGEMENT AND MANAGEMENT CHALLENGES

Annual deposition of sulphur and nitrogen in the Netherlands increased greatly during the last century due to increased emissions from industrial and agricultural sources. The resulting effect of increased nitrogen and acid deposition resulted in the heathland landscape in increased nitrogen availability and increased soil acidification rates. As a result, the succession speed of heathland vegetation types increased as well, and shifts from Calluna dominated heathland into tallgrass (Molinia/*Deschampsia*) dominated heathland occurred on a large scale. In order to restore nutrient poor soil conditions, the topsoil (5-10(15) cm) of large surfaces of wet (*Ericion tetralicis*) and dry (*Genisto-callunetum*) heathland was removed (sod cutting). From 1970 until 2010 BC, this was the predominant management strategy to remove excess nitrogen from the system and this allowed *Calluna vulgaris* to re-establish as the dominant plant species. But current insights point at two major problems of large scale sod cutting: 1) As sod cutting removes the total ectorganic horizon, it not only removes excess nitrogen from the system, but also other nutrients in large quantities, resulting in increased nutrient limitation, particularly phosphorus. 2) sod-cutting does not alleviate the co-occurring soil acidification, which results in highly acidic soil conditions, also hampering the re-establishment of species rich heathlands. Therefore, current management practice has abandoned these large scale measures and focusses on combinations of small scaled activities to reduce the nutrient load of the system. Examples are removal of small tress, burning, mowing, choppering and small scaled sod cutting. As the park is also one of the largest game reserves, including the occurrence of free ranging Mouflon (*Ovis orientalis*), herded grazing by sheep is not used as a management tool due to veterinary reasons (risk of disease outbreak). The grazing pressure of Mouflon and Red Deer is also substantial. Recently, a herd of Danish heathland cows (an old breed of particularly small cows bred specifically for heathlands) was also introduced in the park.

Besides the regular management practice, the Park aims at restoring ecosystem functioning if needed. In the winter of 2013-2014 rewetting measures were carried out



• **Fig 5** • *Results of feeding experiments with female Field Crickets (Gryllus campestris) in the PO_4 and liming experiments at the National Park Hoge Veluwe. Mean daily reproductive success per adult lifespan (+/- 1 S.E.) was significantly lower in liming treatments (Dol+) and significantly higher in PO_4-treatments (P+) compared to control.* Inset: *male and female Field Cricket in the feeding experiment.*

to restore the hydrology of the wet areas of the Park (infilling of ditches; restoration of the original topography; removal of (coniferous) forests and removal of dams and reconstruction of bridges). More recently the Park focuses at restoring the natural soil buffering capacity. This is done by adding fine-grained rocks (rock dust) which tries to restore the natural mineral composition of the soil, and to increase the buffering capacity of the soil. Another major management practice carried out in accordance with rock dust application are the creation of heathland corridors by clear-felling large areas of spontaneous forest stands, in order to connect all open heathland and drift-sand areas inside the park.

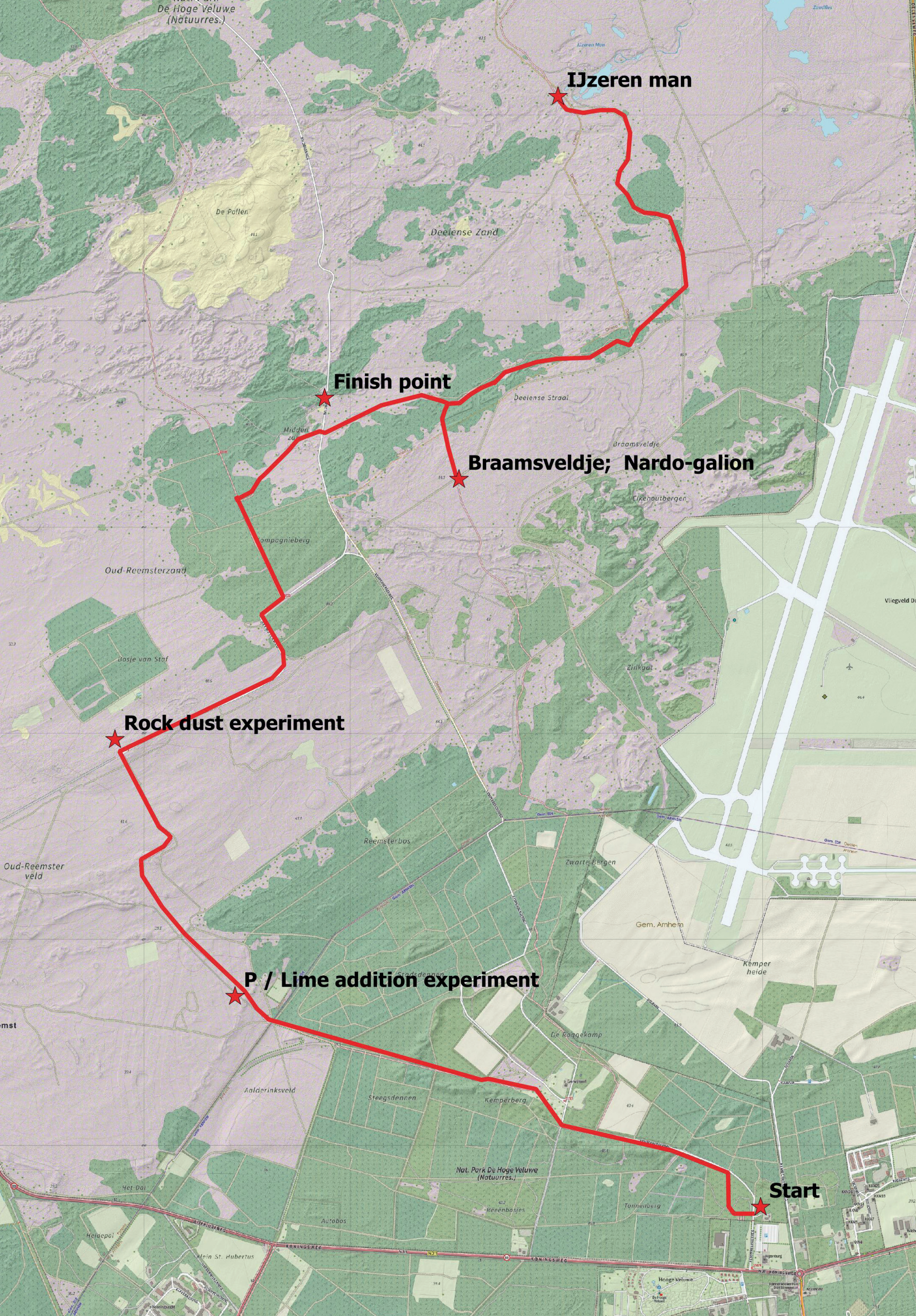
EXPERIMENTS

The National park is home to several scientific experiments. The ones that will be visited during the excursion are briefly described here. In the Southern part of the park, full factorial experiments with addition of lime and/or phosphate were carried out at young, sod cut sites in nowadays *Molinia*-encroached dry heathland vegetation. The experiments were carried out in order to answer some fundamental questions regarding acidification and limitations of the usefulness of sod-cutting as a nitrogen removal management tool (for more information, see Vogels et al 2017). Several peer reviewed articles regarding vegetation response, above and below-ground animal response are currently in preparation and/or under review (Siepel et al., submitted, Vogels et al, in prep). The main conclusions of these experiments are:

1) Sod-cutting hampers the development of a species rich vegetation not only by increasing Al and NH_4 stress, P-shortages also play an important role, as both liming as well as PO_4 addition resulted in a substantial increase in numbers of characteristic vascular plants settling the plots;
2) Alleviating P-shortage has a major significant positive effect on soil mesofauna re-establishment and total soil mesofauna densities, while liming had no significant effect;
3) Alleviating P-shortage has minor but significant positive effects on fitness of the model species *Gryllus campestris* (Fig 5);
4) Addition of lime had a major and significant negative effect on *Gryllus campestris* fitness, as well as Carabid beetle activity-density in the field.

The results are therefore in support of the hypothesis that sod-cutting has major negative implications on the nutrient balance in heathlands stretching beyond nitrogen removal. Although very effective in removing nitrogen, the concomitant removal of other major nutrients (P) as well as the loss of soil buffering capacity results in a rather species poor heathland vegetation, poor in nutrient quality for herbivores. Liming after sod cutting seems to induce new nutrient balance shifts that negatively influence the nutrient quality for herbivores. This is a problem that needs to be addressed in order to effectively re-

• **Fig 6** • Right: *Overview of the National park with bicycling route and excursion stops.*


IJzeren man
Finish point
Braamsveldje; Nardo-galion
Rock dust experiment
P / Lime addition experiment
Start

store habitat quality, and inspired researchers and mangers to initiate experimental rock dust application as an alternative.
Current research projects focus on the question whether rock dust is suitable in mitigating soil acidification and subsequent loss of species and habitat quality. It aims at restoring the natural soil buffering capacity, without potential negative side-effects on food quality. At two sites, two types of rock dust were applied, as well as traditional liming and control in a replicated experimental setting.

Another program, financed by the province of Gelderland is a larger scaled experiment, with the application of rock dust on several experimental plots of 1 ha in size, in several habitat types present in the area: drift sand, psammophilic heathland, dry heathland, dry siliceous grasslands and acidic oak forest. Here monitoring before, during and after application is being carried out and contrasted with 1ha controls. As both programmes are currently still under investigation, only preliminary results are available at the moment. Results are however promising: rock dust application has significant positive effects on base saturation and on decreasing free Al in the soil and therefore, seems to be effective in terms of restoration of soil chemistry. The effects on fauna are still under investigation.

DAY PROGRAMME

Inside the park we try to give a quick overview of striking landscape features, history and past and current research experiments. We will be traveling by bus from the Nijmegen residence towards the Dwingeloo residence this day, with an additional excursion planned in the afternoon. See Fig 6 for a detailed route. For further information regarding the different stops, see the description in earlier paragraphs.

IMPORTANT NOTICE: The excursion will be carried out by bikes, with a total distance of approximately 15 km. If you are unable to travel by bicycle, please inform the organizing committee, you will be transported by car instead.

- **Start:** parking at the Schaarsbergen park entrance
- **Stop 1:** Experimental site with PO_4^{2-} addition and liming in sod cut *Molinia* encroached dry heathland
- **Stop 2:** Experimental site with Rock dust application in dry heathland (*Genisto-Callunetum*)
- **Stop 3:** Braamsveldje: *Nardo-Galion* community at the former German airfield
- **Stop 4:** IJzeren man: a water course fed by acidic stagnating rainwater that runs off the placic horizons in the subsoil
- **Finish:** Pick-up site of the bus at the main road through the park.

Authors: Joost Vogels & Leontien Krul

FURTHER INFORMATION/ FURTHER READING

- Park website: https://www.hogeveluwe.nl/en
- Videos: https://www.hogeveluwe.nl/nl/ontdek-het-park/natuur-en-landschap/ruben-smit-filmt-deelense-veld

- Beukenkamp & Sevink (2005). Natuur en Landschap, in: Beukhof et al (red); De Hoge Veluwe, natuur en kunst: 38-94.
- Bergsma, H., J.J. Vogels, M. Weijters, R. Bobbink, A.J.M. Jansen & L. Krul (2016). Tandrot in de bodem - hoeveel biodiversiteit kan de huidige minerale bodem nog ondersteunen? Bodem 1, 27-29.
- Jansen, A.J.M., J. Bouwman, C. Rövekamp & J. Sevink (2014). The Hoge Veluwe National Park and its wetlands: vision, planning and realisation. De Levende Natuur 115: 253-257
- Vogels, J.J., M. Weijters, R.J. Bijlsma, R. W. de Waal, R. Bobbink, R & H. Siepel (2016). Fosfaattoevoeging Heide. Dutch report with english summary, VBNE, Driebergen, 127 pp.
- Vogels, J.J., R. Bobbink, M. Weijters & H. Bergsma (2016). Het droge heidelandschap in de 21e eeuw: aandacht voor mineralogie en historisch landgebruik. De Levende Natuur 117, 245-250.
- Vogels, J.J., W.C.E.P. Verberk, L.P.M. Lamers & H. Siepel, In press. Can changes in soil biochemistry and plant stoichiometry explain loss of animal diversity of heathlands? Biological conservation.
- Weijters, M., H. Bergsma, R. Bobbink, H. Siepel, J.J. Vogels (2017). Herstel van heide door middel van steenmeelgift - Rapportage 2017, Dutch report with english summary, Provincie Noord-Brabant en VBNE (OBN-2014-58-DZ) 183 pp.

4 Stroothuizen

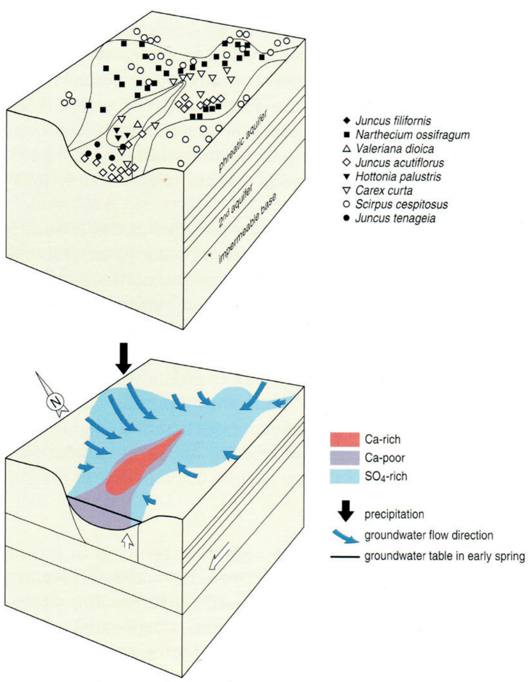
Wednesday afternoon, 23rd of August

SITE CHARACTERISTICS

Stroothuizen was established as a nature reserve in the 1960s. It is part of the nature reserve 'Dinkelland', named after the small river Dinkel that flows through the eastern part of Twente. The reserve is nowadays owned by State Forestry Services. Although small (ca. 35 ha), Stroothuizen is one of the best preserved wet heathlands in the eastern part of the Netherlands.

• *Geology & Soil*

During the Weichselian glacial period this area has been covered by a thin layer of aeolic sandy deposits. Below this thin layer, fine loamy sands, with occasional fine gravel or loam layers, have been deposited by the Dinkel river. Its relief is modest with elevation differences up to 2 meters. It consists of a mosaic of strongly podzolized higher parts and depressions where some organic material has accumulated.



• Fig 1 • *Distribution of characteristic plant species in relation to the distribution of ground- and surface water types in Stroothuizen.*

• *Hydrology*

The name Stroothuizen means: hamlet (huizen) near an elongated slack where often groundwater discharges (stroot). This seepage area used to feed a small rivulet, that no longer exists. The larger part was filled in with sand during the land reclamation works in the 1960s, and only a small trench has remained. The lower parts of the reserve consist of soft-water pools and a long and narrow slack, situated in the northwestern part. Ditches are not present in the reserve, but still water is lost to nearby drainage ditches draining the agricultural fields in the 'Puntbeek' brook valley. Here, the large channel ('Dinkel Omleidingskanaal') has replaced an old rivulet and prevents flooding in wet periods. Once this was a regular phenomenon in large parts of north-eastern Twente but inundations are nowadays tolerated only locally, preferably in nature reserves.

Before restoration measures were carried out four hydrological zones could be distinguished in the north-western part of the reserve (Fig 1). These zones were based on differences in chemical composition of the ground- and surface water. The first zone, characterized by shallow base-poor groundwater, consists of the sandy ridges and their slopes. The water tables in the ridges rise during the winter, leading to a lateral flow of shallow groundwater. This groundwater discharges at the slopes of the ridges. The second zone is situated in the centre and is characterized by the combination of base-rich groundwater and stagnant surface water with moderately high concentrations of calcium. This base-rich water originates from the second aquifer. The third zone with prolonged inundation, also occurs in the centre. Here, base-poor, but relatively sulphate-rich surface water encloses the surface water of the second zone. The groundwater chemistry of this part of the centre is stratiform: a body of relatively calcium-poor water covering calcium-rich groundwater. In between the first and third zone a very small zone of upward seeping moderately base-rich water occurs (this fourth zone is not depicted in Fig 1).

• *Ecological qualities*

Between 1944 and 1953 litter meadows *(Cirsio-Molinietum orchietosum)* and wet heathlands (*Ericetum tetralicis*) were found at the north-western part of Stroothuizen. Wet heathlands with species *Narthecium ossifragum*, *Scirpus cespitosus*, *Lycopodiella inundata*, *Rhynchopspora alba* and *R. fusca*,

• **Fig 2** • *In Stroothuizen sod cutting resulted in the long-term restoration of wet heathlands with high occurrence of Narthecium ossifragum and rich in Sphagnum species.*

Gentiana pneumonanthe, and several *Sphagnum* species had developed at the higher parts, and litter meadows rich in orchids at the lower parts. In the *latter community Carex panicea, Dactylorhiza incarnata, Succisa pratensis, and Parnassia palustris* occurred. The lowest and flattest parts were characterized by a mesotrophic fen community *(Caricion nigrae)*, with species such as *Carex curta, Carex echinata, Juncus filiformis* and *Oenanthe fistulosa,* and alder carr. In the soft-water pools, species such as *Hypericum elodes, Scirpus fluitans, Lobelia dortmanna, Deschampsia setacea, Littorella uniflora, Sparganium angustifolium* and *Potamogeton polygonifolius* occurred. The zone in between the wet heathlands and the fen and soft-water plant communities was grown by shrubs of *Myica gale*.

MANAGEMENT AND MANAGEMENT CHALLENGES

• *Challenges*

Stroothuizen is surrounded by intensively used agricultural areas. The local hydrology of this small reserve is severely affected by drainage activities and groundwater abstraction on behalf of farmers. These inter-

• Fig 3 • *Twenty years after restoration of the former arable land Groener species of litter meadows, such as Galium uliginosum, Juncus conglomeratus, J. acutiflorus, and Lychnis flos-cuculi have built narrow zones on the slope in between dry cover-sand ridges and during winter inundated slacks.*

ferences with the hydrology have a negative impact on groundwater-dependent plant communities in the nature reserves and restrict restoration possibilities. After the nature reserve Stroothuizen was founded in the 1960s, the manager decided to construct a bank along its western border in order to maintain high water levels. As a consequence large parts of the northwestern slack became inundated with base-poor precipitation water during at least four months. Calcareous groundwater could no longer reach the reserve due to drainage ditches along the western border and due to presence of drainage pipes in adjacent arable fields. All this caused lower groundwater tables, acidification and eutrophication. The increased eutrophication may have been a result of increased mineralization of organic material and a higher availability of phosphorus in the soil due to low calcium and iron content in the surface water.

Before restoration measures were carried out the vegetation was highly impoverished. Dry heathlands still occurred at the sandy ridges, while remnants of wet heathlands with *Scirpus caespitosus* and *Narthecium ossifragum* were present at the slopes. During wet periods base-poor water seeped downslope into the slack. Large parts of the wet heathland were dominated by *Molinia caerulea*, leaving little space for *Erica tetralix*. A small sedge vegetation with *Carex curta* and *Juncus filiformis*, was found further downslope, but was threatened by monotonous swards of *Calamagrostis canescens*, *Juncus effusus* and *Agrostis canina*. Here, in the hydrological third zone calcium-poor surface water stagnated for circa 3-4 months and prevented the calcium-rich groundwater to reach the surface. Locally (to the north) a monotonous sward of *Calamagrostis canescens* and *Holcus lanatus* was present. These swards were accompanied by *Juncus acutiflorus*, which points to the discharge of a lateral groundwater flow. Here, the characteristic species of the *Cirsio-Molinietum* disappeared in the late 1960's. The chemical water composition in this (fourth) zone is characterized as moderately base-rich. Here, in winter the discharge of iron-rich groundwater is visible by the rusty red colour of the groundwater on the soil surface. In the second hydrological zone, were alder carr occurred with species such as *Hottonia palustris* and *Valeriana dioica*, base- and iron-rich groundwater exfiltrated. Where the third hydrological zone encompasses the second hydrological zone, rain- and base-poor shallow groundwater, originating from the sandy ridges, stagnated, forming shallow soft-water bodies. Here, small-sedges communities of the *Caricion nigrae* have developed, with species such as *Carex curta*, *Carex echinata* and *Sphagnum palustre*.

- ***Management measures***

The heathland reserves in 'Dinkelland' are rich in elevation differences and, therefore, harbour a wide variety of plant communities: wet and dry heathlands, soft-water pools and mesotrophic wet meadows, which are mown each year and no fertilizers are applied. Occasional sod cutting occurs in the grasslands, pools and heathlands.

In Stroothuizen sods have been cut in several sites with the aim to restore wet heathlands, wet meadows and soft-water plant communties (class *Littorelletea*, community *Scirpetum fluitantis)*. In the first year after sod cutting pioneer communities appeared. *The Lycopodio-Rhynchosporetum albo-fuscae* appeared at acid sites, with *Lycopodium inundadatum, Rhynchpospora alba, R. fusca, Drosera intermedia* and *D. rotundifolia*. The *Cicendietum filiformis (*alliance *Nanocyperion)* arose at base-rich sites, with *Cicendia filiformis, Juncus tenageia* and *Radiola linoides.* Sometimes, species of initial phases of litter meadows, such as *Pinguicula vulgaris* and *Sagina nodosa,* appeared within the first year. However, these species disappeared within 2 to 3 years.

Sod cutting was very successful in restoring soft-water plant communities. Within one year after sod cutting most of the characteristic species established. Wet years (1993 and 1994) resulted in spreading of these species, while dry years (1995, 1996 and 1997), in combination with cold winters in 1995 and 1996, have caused deterioration of soft-water species. Most species could re-establish, but the species of *the Isoeto-Lobelietum* (class *Littorelletea*, alliance *Littorellion*) *Sparganium angustifolium,* and *Lobelia dortmanna,* have disappeared. The groundwater regime of the sod-cut site in the eastern part of the reserve proved to be unsatisfactory: water tables did drop too early and too deep, whereas the period with inundation lasted too short (Jansen et al., 2004).

Sod cutting of wet, acid sites resulted in the restoration of wet heathlands. In Stroothuizen these communities are more persistent than in Punthuizen, a nearby nature reserve highly similar in historical ecological qualities, and more species established in wet sites *(Sphagnum molle, S. cuspidatum, S. magellanicum,* and *Narthecium ossifragum* (Jansen et al., 2004; Fig 2). This is due to higher average groundwater levels in Stroothuizen. In Punthuizen, however, the regeneration of litter meadows was much better after sod cutting. This might be the result of (1) the local groundwater system causing base-rich conditions in the middle part of the gradient, where no inundations occur, (2) the mesotrophic conditions (poor in nitrogen and phosphorus) and (3) the presence of characteristic species in Punthuizen (Jansen, 2000). Many of these have a short-term persistent seed bank type. Depletion of the local seed bank in Stroothuizen could be the reason why ten years after sod cutting only common litter meadow species (*Molinia caerulea, Juncus conglomeratus,* and *Carex panicea*) have re-established. These species were either present before sod cutting or have a long-term persistent seed bank. Species-rich litter meadows require conditions in which phosphorus is limiting the growth of competitive species. Therefore, another explanation for the failure to restore litter meadows in Stroothuizen by sod cutting might be the high phosphorus levels in the top soil. These might be the result of prolonged inundation, leading to dissolution of Fe-P and Al-P minerals under anaerobic conditions (Boeye et al., 1997; Jansen, 2000).

• ***Restoration in a former arable field***

In the beginning of the 1990s 7 hectares of intensively used arable land were purchased adjacent to Stroothuizen. The purchase of this land (named 'Groener') provided new opportunities to decrease the impact of drainage, while at the same time wet heathland could be restored from former arable land (Figure 3). By purchasing this field adjacent to the western border of Stroothuizen, several rewetting measures could be taken during the winter of 1993-1994: (1) filling up the deep ditch and the drainage tubes in the arable land, resulting in an increased groundwater discharge; and (2) levelling the bank to prevent stagnation of surface water, simultaneously sods were cut in some parts of the reserve. The measures resulted in the reduction of the inundated area, limitation of the period of inundation, the reappearance of superficial water flow, and rising of the average lowest water-level, with the exception of the dry year 1996.

Furthermore, the measures have resulted in a more or less stable base-saturation of the top soil in the seepage (second) zone and a decrease of the base-saturation of the top soil in the former inundation (third) zone. Until now, the pH has not changed. The decline of the base saturation in the third zone, corresponding with lower calcium contents in the groundwater, might be due to the higher average water tables, which limit the oxidation of FeS_2 (pyrite) and, therefore, the loss of calcium from the soil. In fact, the higher calcium contents of groundwater and top soil before the measures point to desiccation and acidification of the soil. After rewetting the calcium contents of the groundwater have declined to their natural levels.

In the old part of Stroothuizen the combination of hydrological measures and sod cutting have resulted in:

1) the colonization by new species in the western part, such as *Littorella uniflora, Sparganium erectum ssp. neglectum, Pilularia globulifera, Sagina nodosa, Hypericum quadrangulum* and *Samolus valerandi*. These are species characteristic of moderately base-rich to base-rich sites;
2) an increase of species of small sedge communities *(Carex echinata, Carex curta, Oenanthe fistulosa, Menyanthes trifoliate)* and litter meadows *(Galium uliginosum, Carex panicea);*
3) the colonization by several endangered moss species such as *Phaeoceros carolinus, Anthoceros caucasicus* (last found in the Netherlands in 1926!), *Riccia canaliculata* and *Philonotis fontana*.

The purchased arable land was completely levelled after reclamation from heathland in the 1930s. Before the purchase Maize was grown here and huge amounts of manure and pesticides were used. After purchasing in 1991 Rye was grown, without using fertilizers. During the winter of 1993/1994 the original topography was restored by digging exactly unto the former soil surface. Before removing the top soil layer of the arable field, the original topography was reconstructed by carrying out a detailed soil survey. The removal of the top soil from the arable field was carried out in such a way that the former topography of pools, slacks and ridges was restored and connected to the topography of the adjacent reserve Stroothuizen

Groener target species	1994-1996	2002	2014
Dry & wet heathlands	**9**	**11**	**11**
Drosera intermedia	x	x	x
Calluna vulgaris	x	x	x
Erica tetralix	x	x	x
Rhynchospora fusca	x	x	x
Juncus squarrosus	x	x	x
Molinia caerulea	x	x	x
Genista anglica	x	x	x
Myrica gale	x	x	x
Cytisus scoparius	x	x	x
Gentiana pneumonanthe		x	x
Juniperus communis		x	x
Soft-water pools	**12**	**9**	**7**
Luronium natans	x		
Apium inundatum	x		
Eleocharis acicularis	x		
Echinodorus ranunculoides	x	x	
Samolus valerandi	x	x	
Hydrocotile vulgaris	x	x	x
Scirpus fluitans	x	x	x
Hypericum elodes	x	x	x
Eleocharis multicaulis	x	x	x
Pilularia globulifera	x	x	x
Littorella unifora	x	x	x
Pioneers (alliance Nanocyperion)	**12**	**8**	**1**
Juncus tenageia	x		
Anthoceros caucasicus	x		
Riccia canaliculata	x		
Phaeoceros carolinianus	x		
Riccia glauca	x		
Scirpus setaceus	x	x	
Cicendia filiformis	x	x	
Gnaphalium luteo-album	x	x	
Anthoceros punctatus	x	x	
Blasia pusilla	x	x	
Riccia beyrichiana	x	x	
Juncus capitatus		x	
Carex oederi ssp oederi	x	x	x

Groener target species	1994-1996	2002	2014
Small-sedge communities (Caricion nigrae)	**2**	**6**	**7**
Carex nigra	x	x	x
Veronica scutellata	x	x	x
Juncus filiformis		x	x
Carex curta		x	x
Carex vesicaria		x	x
Oenanthe fistulosa		x	x
Carex echinata			x
Litter meadows (Junco-Molinion)	**12**	**15**	**20**
Junccus alpino-articulatus	x		
Equisetum fluviatile	x	x	x
Galium uliginosum	x	x	x
Lotus uliginosus	x	x	x
Juncus acutiflorus	x	x	x
Ajuga reptans	x	x	x
Carex panicea	x	x	x
Juncus conglomeratus	x	x	x
Hypericum tetrapterum	x	x	x
Rhinanthus angustifolius	x	x	x
Silene flos-cuculi	x	x	x
Parnassia palustris	x	x	x
Pinguicula vulgaris		x	x
Dactylorhiza maculata		x	x
Euphrasia stricta		x	x
Dactylorhiza majalis ssp prae termissa		x	x
Platanthera bifolia			x
Dactylorhiza majalis ssp maj alis			x
Succisa pratensis			x
Luzula multiflora			x
Scirpus sylvaticus			x
Reed swamps	**2**	**4**	**4**
Typha latifolia	x	x	x
Alisma plantago-aquatica	x	x	x
Achillea ptarmica		x	x
Lythrum salicaria		x	x
Total number target species	**49**	**53**	**50**

• **Table 1** • *Characteristic plant species (target species) that have appeared at the former arable land Groener within 3 years, 9 and 21 years after restoration measures have been carried out.*

in order to enable superficial water flow in the whole area.

From the start the development of a more natural vegetation was promising. Already in the first three growing seasons several characteristic species appeared (Table 1). Surprisingly, many heathland species germinated the first growing season after restoration. This might be due to their long term persistent seed banks, and the low nitrogen contents of the soil after top soil removal. All heathland species still occur and have become wide-spread. Others, such as *Juniperus communis* and *Gentiana pneumonanthe* arrived later, originating from the old part of the reserve. Moreover, many soft-water species established the depressions in the first years after the measures were taken. After 9 years some of them have disappeared, especially due to the dry year 1996, and later due to the accumulation of a thin layer of organic material. It was astonishing that so many oligo- and mesotrophic species still were present in the seed bank. Some of these species, such as *Samolus valerandi, Luronium natans,* and *Littorella uniflora* were unknown for (the western part of) Stroothuizen. Pioneer species of the alliance *Nanocyperion*, both herbs and liverworts, established in enormous numbers within the first growing season. The tens of thousands individuals of *Juncus tenageia*, for example, brought a chesnut-coloured haze over the former arable land. After 9 years most of the pioneers had disappeared and after 21 years only one species has remained. Species of litter meadows, small sedge communities and reed swamps are slowly invading the former arable land. The colonisation of (common) species of reed swamps points to locally very wet conditions, which have arisen after the restoration measures were carried out. These species still occur and have built small patches, indicating that the hydrological restoration measures have resulted in a serious rise of the water tables. The same goes for the species of small-sedge communities, which have built a well-developed vegetation in the lower parts of the elongated slacks and other depressions. On the slopes of these depressions an increasing number of species of litter meadows has established (Fig 3). They have built narrow zones which are difficult to assign to a specific, well-developed plant community. They have to be classified as impoverished vegetation of the alliance *Junco-Molinion*. Nevertheless, many characteristic and endangered species have returned. For entire restoration further hydrological measure in the surroundings are required (KWR et al., 2015).

The successful restoration of this former arable land was possible due to (Jansen, 2000):

1) comprehensive knowledge of the hydrological system by making a landscape ecological and a groundwater model in order to gain understanding of the determining hydrological processes;
2) collecting an extensive knowledge of the former topography, by making hundreds of soil borings and interpreting old topographical maps;
3) an outstanding performance of the digging by the crane driver, having much experience and intuition;

4) intensive cooperation between research and management.

DAY PROGRAMME

- During the excursion in Stroothuizen (see Fig 4 for a map of the area), we will concentrate on plant communities which are very characteristic of the area: Atlantic wet heathlands (Ericetum tetralicis), soft-water pools (class Littorelletea), and Atlantic litter (fen) meadows (Caricion nigrae and Junco-Molinion). We will visit a part of the old reserve and a new part (Groener), where many of these plant communities have re-established in a former arable field after restoration measures have been taken.

Author: Andre Jansen

FURTHER INFORMATION/ FURTHER READING

- Boeye, D., D. van Straaten & R.F. Verheyen, 1995. A recent transformation from poor to rich fen caused by artificial groundwater recharge. Journal of Hydrology 169: 111-129.
- Grootjans, A.P., J.P. Bakker, A.J.M. Jansen & R.H. Kemmers, 2002. Restoration of brook valley meadows in the Netherlands. Hydrobiologia 478: 149-170.
- Jansen, A.J.M., 2000. Hydrology and restoration of wet heathland and fen meadow communities. Thesis, Rijksuniversiteit Groningen.
- Jansen, A.J.M., M.C.C. de Graaf, & J.G.M. Roelofs, 1996. The restoration of species-rich heathland communities in The Netherlands. Vegetatio 126: 73-88.
- Jansen, A.J.M., L.F.M. Fresco, A.P. Grootjans & M.H. Jalink, 2004. Effects of restoration measures on plant communities of wet heathland ecosystems. Applied Vegetation Science 7: 243-252.
- KWR, Witteveen + Bos & Royal Haskoning DHV, 2015. Natura 2000 Gebiedsanalyse voor de Programmatische Aanpak Stikstof (PAS) Dinkelland. Report. Provincie Overijssel, Zwolle. pas.natura2000.nl/files/049_dinkelland_gebiedsanalyse_02-09-15_ov.pdf.

• **Fig 4** • *Map of the Stroothuizen nature reserve.*

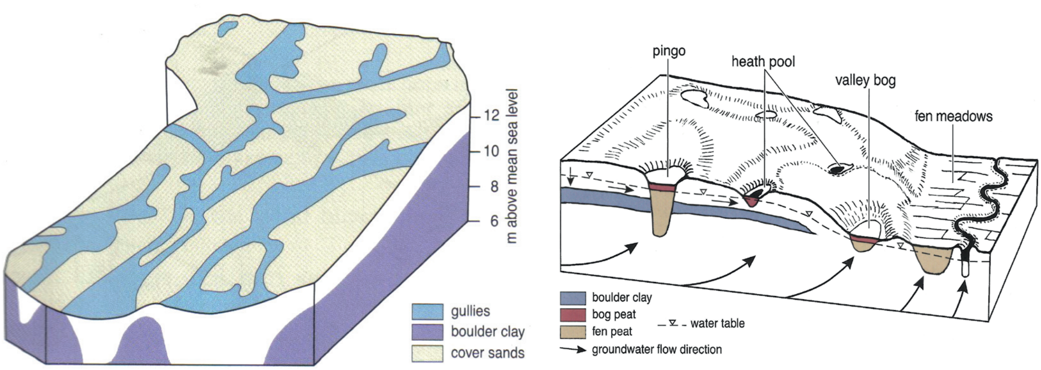
5 Dwingelderveld National Park and Noordenveld restoration site

Thursday afternoon, 24th of August

SITE CHARACTERISTICS

The Dwingelderveld is a nature reserve in the South-west of the province of Drenthe. It is the largest uninterrupted wet heathland reserve in Western Europe. The area contains large areas of wet and dry heath, small heathland bogs, remnants of small raised bogs, drift sands and juniper shrubs. Both the nature values and the location of the area within a virtually intact heathland farming-village landscape are unique. Therefore, the Dwingelderveld was proclaimed as a National Park in 1991. The area covers around 3800 ha and is designated as a protected nature reserve as part of the national ecological network. The Park has been designated a Birds Directive and Habitats Directive area as well.

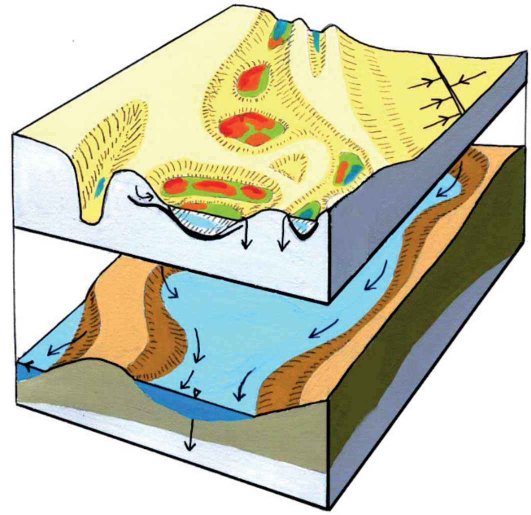
Over 90 species of breeding birds can be found in the Dwingelderveld, including the Common Crane (*Grus grus*). The area is designated for EU birds Directive (79/409/ EC) species such as Woodlark (*Lullula arborea*), Bewick's Swan (*Cygnus columbianus bewickii*), Black Woodpecker (*Dryocopus martius*), Little Grebe (*Tachybaptus ruficollis*), Black-necked Grebe (*Podiceps nigricollis*), Whinchat (Saxicola), Stonechat (Saxicola), Northern Shoveler (*Anas clypeata*), Northern Wheatear (*Oenanthe oenanthe*), Tundra Bean Goose (Anser serrirostris) and Common Teal (*Anas crecca*). The area has also been designated for the rare EU Habitats directive (92/43/ EC, appendix II) protected Northern Crested Newt (*Triturus cristatus*). The Province of Drenthe is the competent authority and has the ultimate responsibility for setting up the Natura 2000 Dwingelderveld management plan.



• **Fig 1** • *Simplified geology and geomorphology of the Dwingelderveld area (top) and heath pool types in the Dwingelderveld (bottom). The small bogs along the valley slopes and in the pingo remnants were once influenced by groundwater, but are now fed by precipitation water. The pools above the boulder clay have always been fed by precipitation water, and may have been formed relatively recently.* - After Bakker et al., 1986 and Grootjans & van Diggelen, 1998.

The Province is ensuring that the objectives for the area are achieved. Staatsbosbeheer (State Forestry Service) and Natuurmonumenten (Dutch Society for the Preservation of Nature) own and manage the largest fraction of the Dwingelderveld reserve.

With 822 mm mean annual precipitation, the Dwingelderveld is one of the wettest parts of the Netherlands. In the area a thick layer of boulder clay was deposited in the subsoil by glaciers in the Saalien glaciation, retaining much of the precipitation water within the area (Fig 1) and leading to a complex hydrology and different heathland pool types. The different gradients in water tables and the occurrence of boulder clay in the upper soil layers has led to a varied heathland vegetation, with *Erica tetralix* dominating the wet parts, sometimes co-dominated by *Sphagnum* species. In the dryer parts *Calluna vulgaris* and/or *Empetrum nigrum* is co-dominant. On soils with higher buffer capacity (boulder clay), *Gentiana pneumonanthe* and *Arnica montana* can be found. Some hundred years ago, drift sands were extensive in the dry sandy parts of the Dwingelderveld due to intensive land use and high stocks of herded sheep. Since the beginning of the 1920's afforestation of the drift sand area with pine trees was carried out. In 1936 about 50 ha of agricultural land was created in the center of the heathland area, which expanded to circa 200 ha in 1950; this is the Noordenveld area. These land use changes occurring in the past 100 years had severe implications on hydrological conditions, resulting in local and subregional degradation of habitat quality.

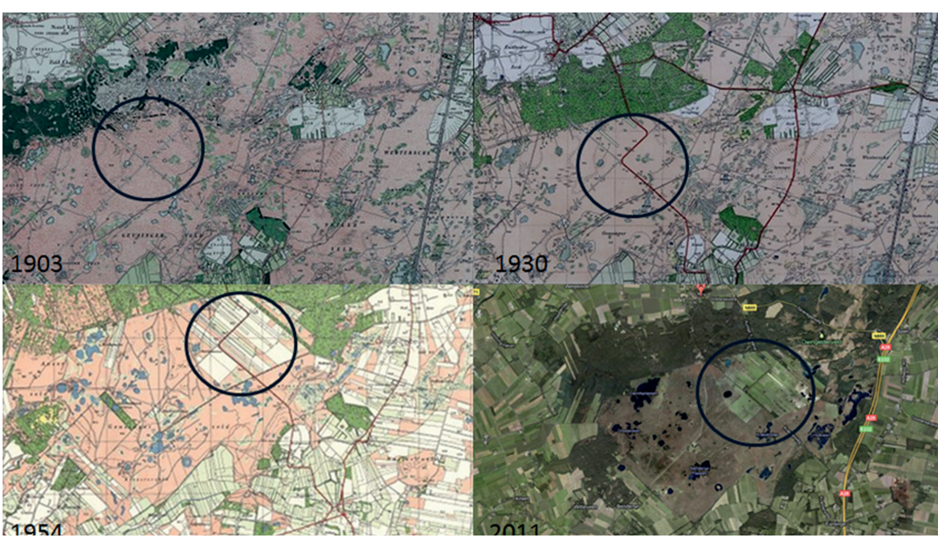


• Fig 2 • *Position of small heathland bogs (orange) in former gullies (yellow), which are underlain by impervious podzolic layers (B-horizons; black) and organic deposits (gyttja). The arrows indicate groundwater flows. The top segment shows the groundwater flows within the shallow sand layer (up to 5 meters). The bottom segment (5-10 meter below ground surface) indicates groundwater flow above the boulder clay deposit (brown and grey colors), which have a high resistance to downward water flow if the layer is more than 2 meters thick. When the boulder clay layer is less than 50 cm thick, groundwater infiltrates to lower sandy layers and flows to the small (drained) river valleys situated on both sides of the Dwingelderveld. The boulder clay layer are the brown layers (from Grootjans et al. 2003). Due to the complicated geological structures several different water levels can be distinguished in and around the heathland bogs.*

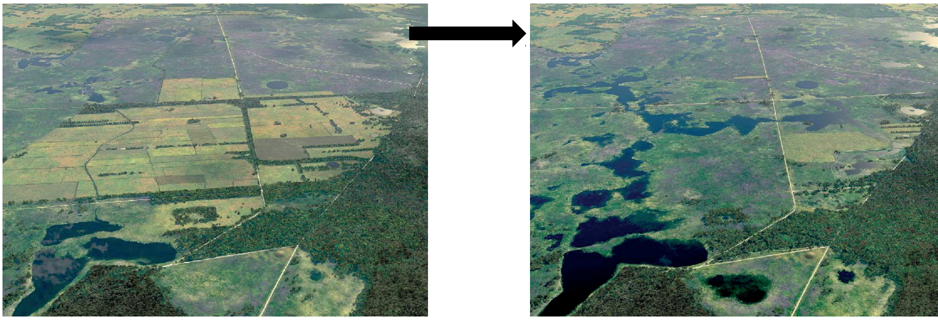
• ***Complex hydrology***
Fig 2 shows a conceptual model of possible groundwater flow in and around the heathland bogs in the Dwingelderveld. The bogs itself are mainly found in old gullies, which are remnants of past (erosive) surface water systems. These gullies have been filled with much larger bogs in the past. Most of these bogs have disappeared, partly by exploitation by man, but possible also due to desiccation of the area as a result due to regional hydrological changes in surrounding plateaus and river valleys. These former bogs however left a mark in the form of impervious organic layers in the subsoil (gyttja and podzolic layers). The present bogs are in fact regenerating Sphagnum mats that are floating on the water, as farmers had already extracted most of the peat during the past centuries.

MANAGEMENT AND MANAGEMENT CHALLENGES

As in many areas in the Netherlands, nitrogen deposition is a problem in the Dwingelderveld area, leading to grass encroachment and soil acidification. Also, as mentioned earlier, desiccation caused by land use change is a problem in the Dwingelderveld (Fig 3). Deep drainage ditches were dug, lowering the water table to 70 cm below the surface. The drainage water from the agricultural enclave also flooded some of the remaining oligotrophic heath pools, resulting in severe eutrophication. Another problem was severe desiccation of the brook valleys situated on both sides of the Dwingelderveld. The combination of agricultural ditches, pine afforestation (which have higher evapotranspiration rates) and changing water tables in the brooks led to severe desiccation in large



• **Fig 3** • *Development of the Dwingelderveld nature reserve in time, Noordenveld in the black circle.*



• **Fig 4** • *Artist impression of the Noordenveld before and after restoration.*

parts of the Dwingelderveld National Park. The Province of Drenthe, Staatsbosbeheer and Natuurmonumenten have jointly implemented a large restoration project partly within the framework of the European LIFE program. The three partners were all aiming for the same target: fighting desiccation, eutrophication and acidification in the Dwingelderveld, increasing the surface area of wet heath, improving the quality of the habitat types and associated flora and fauna. The presence of a former agricultural enclave 'Noordenveld' in the heart of the Natura 2000 area Dwingelderveld was a serious threat to successful hydrological restoration of the Dwingelderveld. The Noordenveld had a draining effect on the valuable habitat types and caused desiccation, eutrophication and acidification of the surrounding heathlands and bogs.

After 40 years Natuurmonumenten and Staatsbosbeheer succeeded in procuring the last agricultural plots in the Noordenveld. Further hydrological restoration of the Dwingelderveld was possible and the transformation of the fertilized grassland of the Noordenveld into dry heath (H4030), wet heath (H4010) and even bogs became new targets in the proposed LIFE project (Fig 4). The development of former agricultural enclave the Anserveld and measures to restore bog ecosystems within in the heathland contributed to this objective. In addition, the Dwingelderveld was suffering from noise disruption due to its location, right next to the A28 motorway. The second project aim was thus to reduce noise levels in the area by creating a soundbarrier between the Dwingelderveld and the motorway, and by improving the ecological connection between Dwingelderveld and Terhorsterzand by creating wildlife corridors on both sides of the motorway. In 2011 the removal of the nutrient rich former agricultural soil started, after extensive studies. The soil was then used to build a soundbarrier and a wildlife passage near and over the A28.

EXPERIMENTS

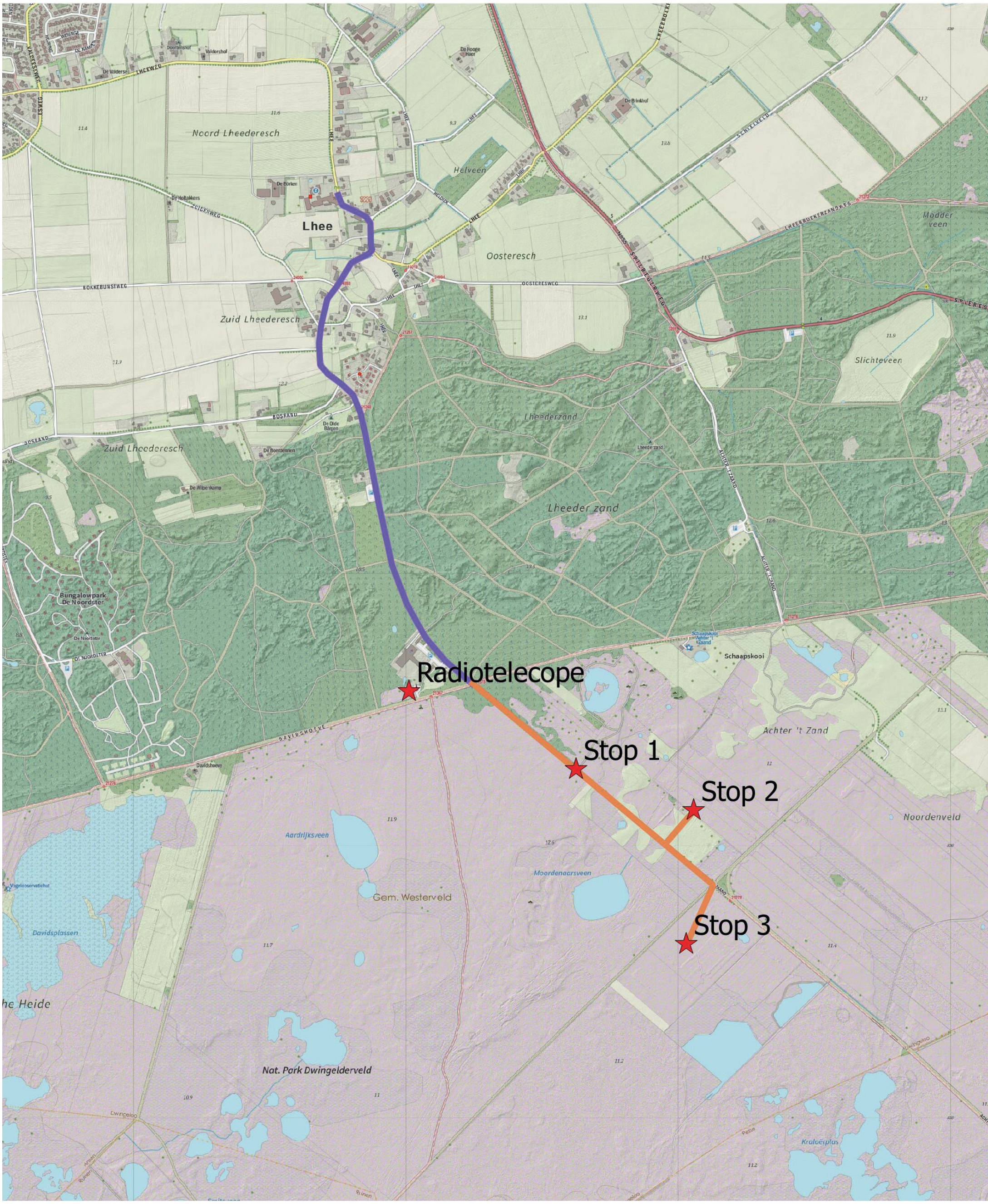
In the former agricultural area of the Noordenveld three experiments are being

• **Fig 5** • *Aerial photograph of the experimental site in February 2012. (dry site in purple and wet site in blue). Clearly visible are the at that time still unexcavated agricultural soils surrounding the experimental plots and the mounds of removed topsoil next to the dry site.*

conducted. The first is an experiment aiming at developing restoration tools for *Nardo-Galion* grasslands on former agricultural soils. This experiment includes soil inoculation and introduction of plant species by fresh hay and seeds. The second experiment is aiming on restoration of both wet- and dry heathland (Fig 5) on former agricultural soils, and includes soil pH manipulation and addition of fresh hay and sods. These experiments will be visited during the excursion and the main results are presented during the EHW by Roos Loeb, Rik-Jan Vermeulen and Maaike Weijters.

DAY PROGRAMME

- We go to the Dwingelderveld by bike, starting from the hotel. The group will be split into three, each group visiting three "information points" (Fig 6). At the stops you will get information on the hydrology and geology of the Dwingelderveld, on the large restoration project of the Noordenveld and we will take a look at the experimental site where different restoration methods are tested to restore heathlands on former agricultural fields. The field visit will be finalized by a guided tour to the Dwingelderveld Radio Telescope, constructed here for the



• **Fig 6** • *Route from the hotel (purple) and through the area (orange) with stops located as stars on the map.*

IN MEMORIAM: PIET DEN BOER

By Rik-Jan Vermeulen and Hans Turin

Last year, in December 2016, Piet den Boer passed away. Piet den Boer was the last of the 3 famous European carabidologists, beside Carl Lindroth and Hans-Ulrich Thiele, who formed the modern carabidology. His most famous contribution was his theory called: "Spreading of risk and stabilization of animal numbers" in 1968. Until that time it was generally assumed that animal numbers were regulated by biotic factors, especially by population density. Since 1959 a large heathland area, close to the Biological Station of Wijster was sampled at several localities for ground beetles. This area can be considered as a large habitat island situated in surrounding agricultural land. Over the years several ground beetle subpopulation or interaction groups appeared to fluctuate asynchronously although the total numbers caught in this area were stable. Small groups of animals could increase or decrease by simple stochastic processes rather than by regulating processes. With the island theory of MacArthur and Wilson in mind, this brought him to the idea that species need a certain area of habitat to persist in a long-term presence in the area, depending on radius of action and size of the species. New in this theory was that, also in mainland habitat islands, isolation and fragmentation could lead to local extinction of species. In the years after, it became generally understood that areas of nature should be as large as possible or at least be connected by dispersal corridors in order to prevent local and regional extinction of distinct species. This is especially true, where it concerns ecological specialists. The earlier view that, if a habitat has the right quality, a species will settle it by itself was abandoned. Subsequently, nature managers and policy makers started to enlarge nature reserves and build connective structures like ecoducts over habitat barriers, for instance, over highways. The Noordenveld restoration project could in this respect also be regarded as a hommage to his work.

low level of background radio noise in the (for dutch standards) lowly populated area of the Dwingelderveld area.

Authors: Maaike Weijters & Ab Grootjans

FURTHER INFORMATION/ FURTHER READING

- Bakker, T.W.M., I.I.Y. Castel, RH. Everts & N.P.J de Vries (1986). Het Dwingelderveld, een Drents heidelandschap. Pudoc, Wageningen. 198 pag.
- Grootjans, A.P. & Van Diggelen, R. (1998). Selected restoration objects in the Netherlands and NW Germany: a field guide. 2nd Conference of Restoration Ecology Groningen. Laboratory of Plant Ecology, University of Groningen, First edition. 120pag.
- Grootjans A.P., Adema, E.B., Baaijens, G.J., Rappoldt, K. & Verschoor, A. (2003). Mechanisms behind restoration of small bog ecosystems in a cover sand landscape. Archiv für Natursch.Landschaftsf. 2003: 43-48
- Weijters, M., Van der Bij, A., Bobbink, R., Van Diggelen, R., Harris, J., Pawlett, M., Frouz, J., Vliegenthart, A. & Vermeulen, R. (2015). Praktijkproef heideontwikkeling op voormalige landbouwgrond in het Noordenveld Resultaten 2011-2014. B-ware research centre, Nijmegen. 148 pag.
- Dwingelderveld 2017 Youtube video
- https://www.youtube.com/watch?v=hb1QFvsdia0
- Dwingelderveld 2015, just after big restoration. Youtube video's
- https://www.youtube.com/watch?v=OkXvyQZUXoM
- https://youtu.be/eDC_H-sdB48

Link to the report of the heathland restoration experiment:

- http://www.nationaalpark-dwingelderveld.nl/publish/pages/115391/rapport-praktijkproef-dwingelderveld.pdf

6 Bargerveen ombrotrophic bog

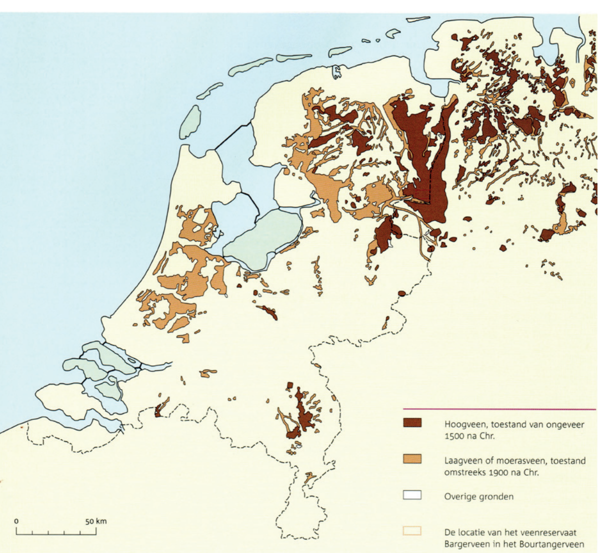
Friday afternoon, 25th of August
PLUS-programme only!

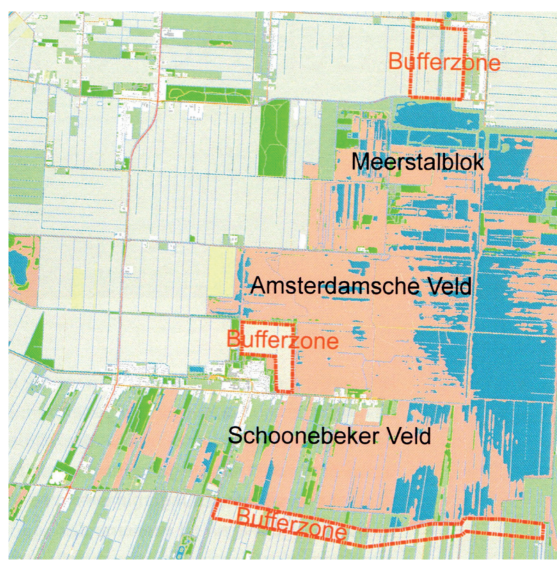
SITE CHARACTERISTICS

Within the Netherlands the Bargerveen Reserve is one of the largest bog remnants and also the one where restoration is the most promising. The reserve is managed by Dutch State Forestry service. The Bargerveen Reserve is a very small remnant (23 km^2) of the former Boertanger Moor (3,000 km^2), which once formed the border between Germany and the Netherlands (Fig 1). The development of the bog complex was studied in detail by Casparie (1972).

Fig 2A shows an impression of the southern part of the former Boertanger Moor, where several raised bog domes had merged to form one large bog complex. A small river (Runde) was exporting excess surface water towards the river Hunze. Between the domes a large dystrophic lake (Zwarte Meer = 'Black Lake') was present. Because the bogs were dome-shaped, precipitation water flew from the top of the bog through the acrotelm (=living top layer of *Sphagnum*) to lower areas. Infiltration into the mineral underground was almost totally prevented by the presence of boulder clay layers in the subsoil, the almost impervious lake sediments and other impervious organic layers. The bog complex was not only fed by precipitation water: locally groundwater from surrounding sandy ridges could enter the complex through so-called 'hydrological windows' where the boulder clay layers had eroded away (Casparie & Streefkerk 1992).

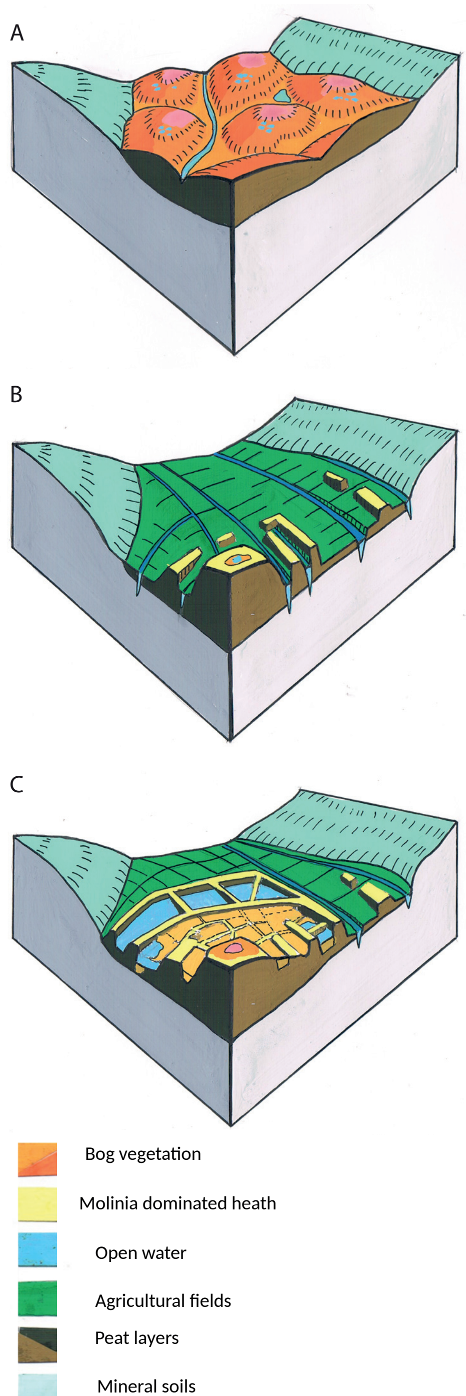
Only a very small part of the Dutch side of the Boertanger Moor has not been subject to peat extraction. This area, part of the





• **Fig 1** • Left: *The location of the former Boertanger Moor bog complex (largest brown patch) on the border of Netherlands and Germany.* Right: *the present Bargerveen Reserve.*

• **Fig 2** • A: *Impression of the southern part of the former Boertanger Moor consisting of various large bogs that had merged to one large bog complex. The yellow square represents the present extension of the bog relict Bargerveen.* B: *Impression of the cutover and largely reclaimed peatland with in the lower corner the small bog remnant Meerstalblok before the start of restoration.* C: *Impression of the present bog reserve Bargerveen showing restored bog vegetation around the core reserve (Meerstalblok in the foreground) and large flooded buffer zones on former agricultural land.* - Figure drawn by Ab Grootjans.



Meerstalblok, was the only place where typical bog vegetation and a small bog lake (in Dutch 'meerstal') had remained before the area was declared a nature reserve in 1968 (Fig 2B). Although drainage and burning of the top layer for growing Buckwheat was practiced here, typical plant and invertebrate species still persisted in the area (Van Duinen, 2013). The bog remnant is situated 4 meter above the surrounding area, where large scale peat extraction in the 19th and 20th century has left some small strongly desiccated bog remnants amidst areas with shallow remaining peat layers that were transformed into pastures and arable fields.

MANAGEMENT AND MANAGEMENT CHALLENGES

Since 1971 a network of smaller peat dams and more recently large dikes have been built in order to raise the water levels in

• **Fig 3** • *The central part of the bog reserve Bargerveen showing the restored bog vegetation growing at almost the same height as the peat dikes that have been built to raise the water level with several meters.* - Photo: André Jansen, December 2014.

• **Fig 4** • Left: *deeply drained agricultural fields.* Right: *peripheral hydrological buffer zone to keep the water levels in the Bargerveen bog reserve high.* - Photo: André Jansen.

the reserve (Fig 2C). Because of the very large height differences between the areas with thick remaining peat layers and the cut-over areas, nearly all low lying areas became almost permanently flooded. In the central part of the reserve the regrowth of Sphagnum and Eriophorum species was good. Currently, several hectares are now classified as active raised bog (H7110A). In case of open water *Sphagnum* starts floating when sufficient methane and carbon dioxide is produced by the underlying substrate (Lamers et al. 2002), which may consist of peat or litter formed by grasses or trees. *Sphagnum* mats keep floating for a long time in case little decomposed *Sphagnum* peat is present (Tomassen et al, 2004) or when slightly calcareous groundwater enters the peat from below and stimulates decomposition (Smolders et al, 2003). In the low-lying areas with shallow peat layers and permanent flooding, Sphagnum growth is much more limited.

The grass species *Molinia caerulea* expanded massively after rewetting. Experimental research in the field and in the laboratory revealed that the vigorous growth of *Molinia* was caused by high nitrogen deposition from the air (Limpens et al. 2003, Tomassen et al. 2003). In the Bargerveen area the atmospheric N-deposition in the last decades reached 20-40 kg N $ha^{-1}yr^{-1}$. Critical loads for bogs are 5–10 kg N $ha^{-1}yr^{-1}$, above which the Sphagnum species are unable to absorb the nitrogen (Lamers et al, 2000) and nitrogen becomes available for vascular plants such as *Molinia caerulea* and *Betula pubescens*. Above 18 kg of N $ha^{-1}yr^{-1}$ the vascular plants start to shade the *Sphagnum* plants to the extent that their growth is reduced considerably (Limpens et al, 2003). In the Bargerveen Reserve the rapid growth of grasses and shrubs has been suppressed by introducing sheep and cattle grazing in the area. This has stimulated the growth of Sphagnum to the extent that in the best rewetted areas in the Meerstalblok *Sphagnum* has become dominant and grazing is no longer necessary. The final touch to rewetting of the central parts of the reserve was given by the establishment of large buffer zones on agricultural land around the reserve, where very high water levels were installed. The farmland was acquired by the government. Fig 3 shows that as a result the high peat dikes in the central parts of the bog remnant are nowadays almost overgrown by bog vegetation.

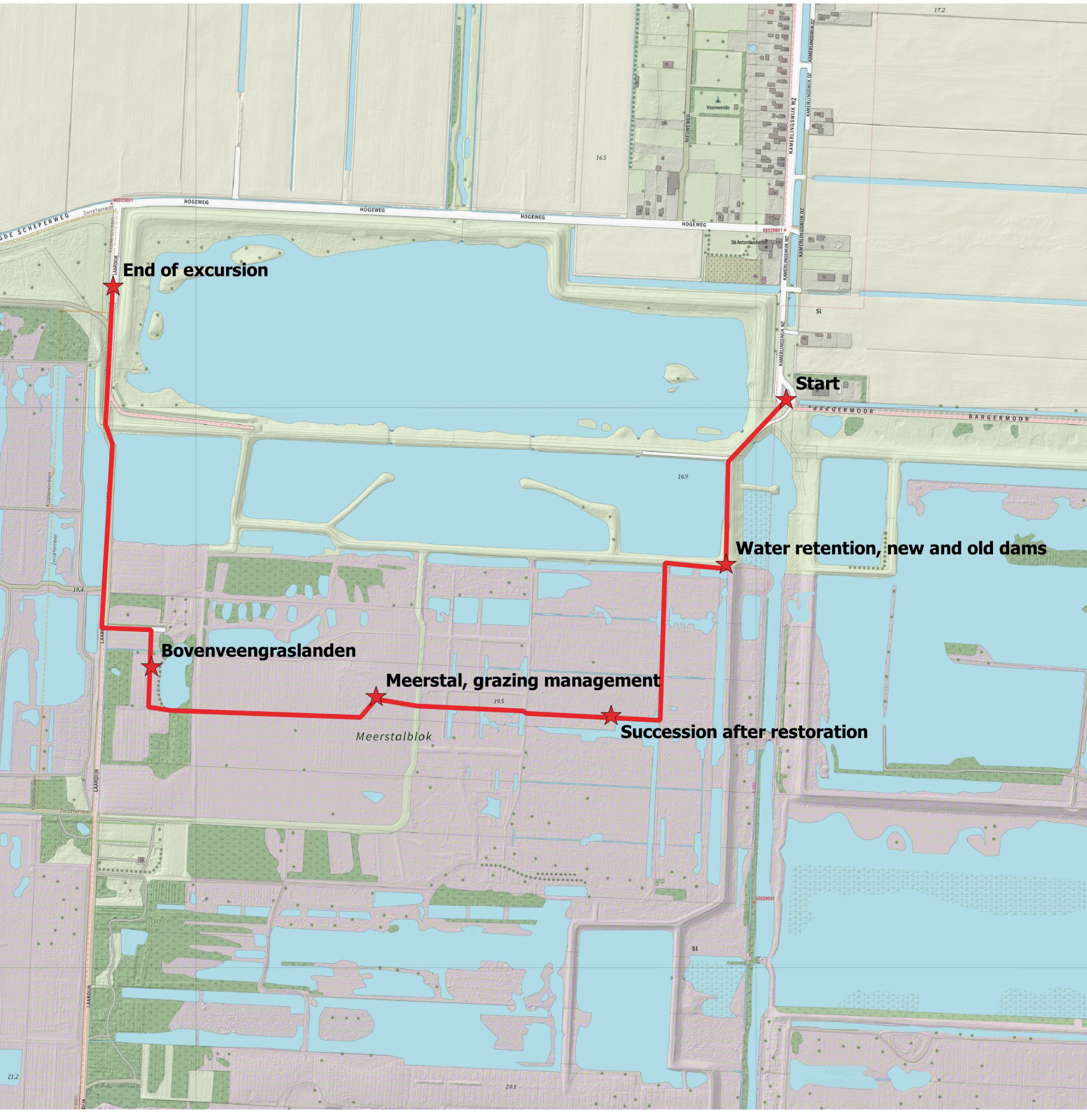
The total budget scheduled for the period 2013-2026 for further measures to restore the Bargerveen bog amounts to about 34 million Euro, including 30 million for restoration measures and hydrological buffer zones and ca. 4 million for continued management of the reserve. These funds come from the Provincial government, the national government and the European Union.

The hydrological buffer zones surrounding the bog relic are 500-800m wide on the Dutch side. The German authorities are planning a hydrological buffer zone of 300m wide at the eastern border of the reserve. The hydrological buffer zones are largely established and planned on cut-over peatlands with shallow layers of (black) peat that have been intensively fertilized and are extremely rich in nutrients, in particular phosphate. After rewetting these former agricultural lands are highly productive and species like Reed (*Phragmites australis*) and Common Cattail (*Typha latifolia*), or Willow (*Salix* spp.) dominate the vegetation within a few years. Harvesting these crops is possible with machines that are adapted to driving in marshes and shallow water. Currently, a pilot project is starting to explore the productive use of rewetted agricultural fields on peat (Paludiculture.com; Wichtmann et al, 2016).

DAY PROGRAMME

- The excursion starts at the office of State Forestry Services (Staatsbosbeheer). We will walk to the remaining small bog lake 'Meerstal' and pass the buffer area and water retention basins (Fig 5). We will also see the differences between the older peat dams and the more recent large dikes constructed to raise the water table in the bog remnant. The vegetation succession following rewetting of poorly humified peat and the effects of sheep grazing can be observed during our walk in the Meerstalblok. A last stop will be on one of the remaining pieces of 'bovenveengraslanden', which consists of grasslands that have been used for agriculture in the past by adding sods and manure to the peat remnants. These grasslands are surprisingly often very rich in plant and invertebrate species, but their preservation is difficult with the raised bog being restored around them.

Authors: Gert-Jan Van Duinen & Ab Grootjans



• **Fig 5** • *Excursion route through the Bargerveen bog with stops marked as stars on the map.*

FURTHER INFORMATION/ FURTHER READING

- http://www.paludiculture.com

- Casparie, W.A. (1972) Bog development in south-eastern Drenthe (the Netherlands). Vegetatio 25: 1-271.
- Casparie, W A. & Streefkerk, J.G. (1992). Climatological, stratigraphic and palaeo-ecological aspects of mire development. In: Fens and Bogs in the Netherlands: Vegetation, History, Nutrient Dynamics and Conservation (ed. J.T.H. Verhoeven), pp. 81-129. Kluwer Academic Publishers, Dordrecht.
- Lamers, L.P.M., Bobbink, R. & Roelofs, J.G.M. (2000). Natural nitrogen filter fails in raised bogs. Global Change Biology 6, 583-6.
- Limpens, J., Berendse, F. & Klees, H. (2003). N-deposition affects N availability in interstitial water, growth of Sphagnum and invasion of vascular plants in bog vegetation. New Phytologist 157, 339-47.
- Smolders, A. J. P., Tomassen, H. B. M., Pijnappel, H. W., Lamers, L. P. M. & Roelofs, J. G. M. (2001). Substrate-derived CO2 is important in the development of Sphagnum spp. New Phytologist 152, 325–332.
- Smolders, A. J. P., Tomassen, H. B. M., van Mullekom, M., Lamers, L. P. M. & Roelofs, J. G. M. (2003). Mechanisms involved in the re-establishment of Sphagnum-dominated vegetation in rewetted bog remnants. Wetl. Ecol. Manage. 11, 403–418.
- Tomassen, H.B.M., Smolders, A.J.P., Van Herk, J.M., Lamers, L.P.M. & Roelofs J.G.M. (2003). Restoration of cut-over bogs by floating raft formation: an experimental feasibility study. Applied Vegetation Science 6, 141-52.
- Tomassen, H.B.M., Smolders, A.J.P., Lamers, L.P.M. & Roelofs, J.G.M. (2004). Development of floating rafts after the rewetting of cut-over bogs: the importance of peat quality. Biogeochemistry 71, 69-87.
- Van Duinen, G.A. (2013) Rehabilitation of aquatic invertebrate communities in raised bog landscapes. PhD-thesis, Radboud University Nijmegen.
- Wichtmann, W., Schröder, C. & Joosten, H. (2016) Paludiculture – productive use of wet peatlands. Schweizerbart Science Publishers, Stuttgart.

THE EUROPEAN HEATHLANDS NETWORK

The European Heathlands Network has been established to enable all persons involved or interested in ecological research, conservation of wildlife, and in policy formulation and implementation in relation to European heathlands to meet, to stimulate discussion, to promote communication, to further the understanding of heathland ecosystems and to disseminate information as widely as possible.