**Review**

**André Jansen and Ab Grootjans (eds):**

***Hoogvenen: Landschapsecologie, behoud, beheer, herstel***

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*Reviewed by Henry Hooghiemstra*

This book is about peatlands in the Netherlands. Edited by André Jansen and Ab Grootjans, who are two experts in the field of peat and landscape ecology, it is richly illustrated, featuring informative figure legends, as well as English summaries along with the use of Latin plant names, making *Hoogvenen* ('bogs') likely also of interest and accessible to those from outside the Dutch speaking part of the world. In a nutshell, it describes how a gift from nature, consumed by humans, is being conserved in its final stage of existence.

In flat coastal areas, nature sequestered huge amounts of atmospheric carbon in peatlands. This occurred during periods of sea level rise. Further inland, at higher elevations, sea level rise caused the water on its way to the sea to stagnate in the river valleys. That is where peatlands developed. Peat consists of undecomposed plant remains. As this water-soaked plant mass makes no contact with the air, it is protected from decomposition. It harbors a lot of carbon and hydrogen, which are the carriers of energy. Plants use energy from the sun and produce their plant tissues with a photochemical process (photosynthesis). In undecomposed plant tissue much energy is left. After sea level rise the opposite takes place and thick coastal peat layers are covered by sands (the source of sandstone) and clays (the source of shales). Millions of years later, these buried and compressed plant remains developed into natural oil and gas. Thus, the earth has accumulated and stored huge amounts of energy in endless numbers of cycles of sea level change.

The last natural cycle of sea level change was interrupted by humans when the big ice sheets were rapidly melting. Rising sea levels caused the coastline to be pushed higher on the continental slope. As coastal areas are attractive for settlements, the coastal parts in the Netherlands became occupied by humans around 5000 BC at the start of the Neolithic Period (Vos et al. 2020). The peat previously accumulated during the Holocene had no chance of further increasing in thickness and being buried afterwards in the natural cyclical process that would have followed. Humans tried to control the design of the coastal area themselves. In the Netherlands, peat started to expand in coastal areas about 8000 years ago and around 2500 years ago peatlands reached their maximum expansion, covering more than half of the Netherlands. Since Roman times, the draining of peatland to improve accessibility for exploitation increased rapidly. Sun-dried blocks of peat became a source of energy and salt was produced by burning peat which had been soaked with seawater. Peat drainage and extraction disturbed the natural defense capabilities of coastal peatland. Peatlands were eroded by the sea and dramatic losses of land surface were first experienced in the province of Zeeland. At higher ground, in the provinces of Drenthe, Overijssel, and Brabant, peat developed from the Middle Ages onwards as the most important source of energy. Beginning in the 17th century, these provinces provided rapidly growing cities in the western parts of the Netherlands and Flanders with fuel. During the era of industrialization, the role of low-energetic peat became replaced by high-energetic coal. In the 19th and early 20th centuries peat was industrially harvested at an unprecedented speed and today only fragments of peatland are left.

*Figure 1a. Dike in Bargerveen separating the nature reserve into hydrological compartments. The dike surface is relatively dry and covered by* Vaccinium *dominated vegetation in mid-September 2012. To the left and right peatland is in restoration. In the background the open water reflects an earlier stage of restoration. Photo by Henry Hooghiemstra.*

Physical geographers have calculated that the Netherlands lost 99% of its peatland during the last millennia, reflecting a loss of about 24 km3 of peat. The tiny remnants form "peat monuments" in the Dutch landscape. The undecomposed plant remains, leading to peat, are either in contact with nutrient-rich ground-water, producing fens, or they are hydrologically isolated from deeper soils and totally dependent on nutrient-poor rainwater, resulting in bogs. Today, all Dutch bogs are restricted to being a nature reserve, an example of which can be seen in Figure 1a and Figure 1b. Until recently, former peatlands were of military importance, given that it was hard to cross such a landscape. The military chose peatlands to form a natural border between countries, as has been the case between the Dutch province of Drenthe and Germany. The study of the macro-scopic plant remains itself was initiated for military-economic reasons, too. When oil supplies were embargoed during the First World War, governments realized peat could be used as an alternative source of energy. Initial peat studies from 1916 by the Swedish geobotanist Lennert von Post (Birks and Berglund 2017) tried to assess peat's distribution and volume, estimating the potential energy stocks and addressing the question to what degree peat could be used to satisfy the country's demand for energy. Succow and Joosten (2001) published a first landscape ecological overview of peatlands. A thorough compilation of mires and peatlands in all European countries was elaborated on by Joosten et al. (2017). For North America and Canada, the studies by Ritchie (1987), Woo (2002) and Matthews (1989) provided well-illustrated accounts of how mires and peatlands have developed since the last ice age.

*Figure 1b. Hydrological compartment in Bargerveen showing a phase in bog regeneration. Floating* Sphagnum *in the shallow water body, surrounded by* Juncus *vegetation transitional to bog covered by* Betula *trees in mid-September 2012. Photo by Henry Hooghiemstra.*

Returning to the book *Hoogvenen* itself, it provides scientific understanding, while remaining an easy-to-read text, as it discusses the last tiny fragments of peatland in the Netherlands and introduces the reader to a little-known landscape. The book summarizes in chapters 1 to 13 what is understood about bogs in general and how they function. Chapters 14 to 31 present information about the Dutch bogs, while their potential future is discussed together with the required measures. Chapter 32 shows how the European *Natura 2000* conservation regulations do not adequately protect Dutch bogs and chapter 33 is a reflection on the current status of bogs, showing what the future may hold. The book contains a helpful glossary, references, an index, and the professional affiliations of the 59 contributing authors, whose aim is to share their knowledge with active professional nature conservationists, as well as with students in related disciplines.

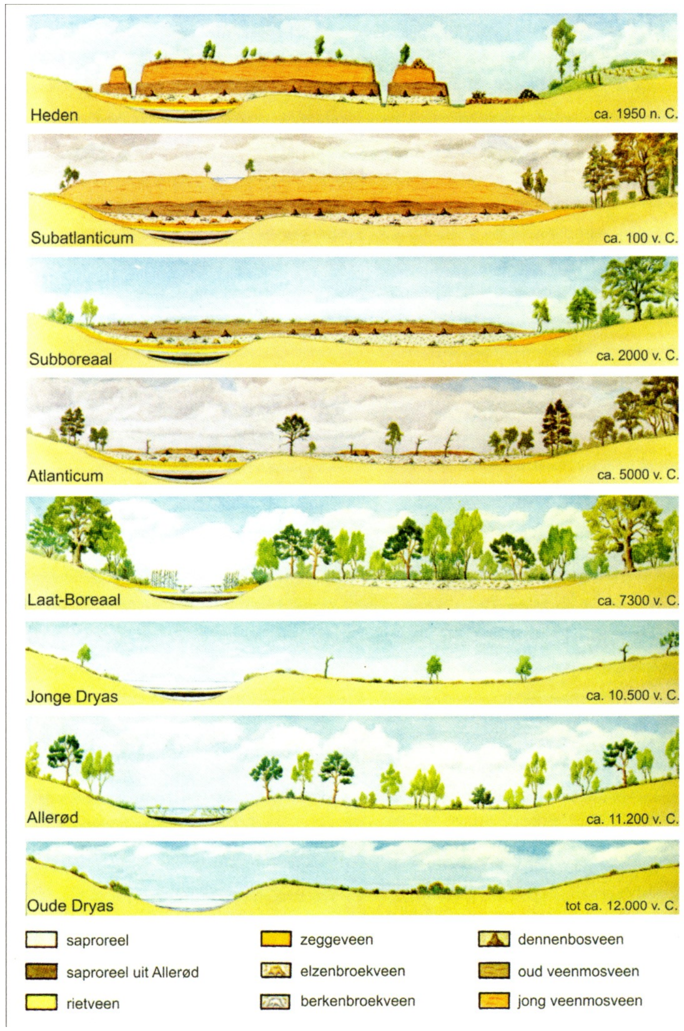


*Figure 2. Development of a bog over the course of eight time periods from 12000 BC to 1950 AD (Van der Linden and Kooistra 2019, 97).*[1] *Reproduced from* Hoogvenen: Landschapsecologie, behoud, beheer, herstel *with permission.*

[1] English translations for the Dutch terms used in the legend at the bottom of Figure 2: *sapropeel* 'sapropel'; *sapropeel uit Allerød* 'sapropel from Allerød interstadial'; *rietveen 'Phragmites* peat'; *zeggeveen* '*Carex* peat'; *elzenbroekveen* '*Alnus* dominated peat'; *berkenbroekveen* '*Betuta* dominated peat'; *dennebosveen* 'peat with substantial input from *Pinus'*; *oud veenmosveen* 'old *Sphagnum* peat'; *jong veenmosveen* 'young *Sphagnum* peat'.

Opening this volume, the bizarre, wet, acid, colorful and open panoramic landscape of bogs (‘*hoogvenen*’) is displayed. Chapter 1 presents a schematic cross section of a bog to illustrate its typical hydrological characteristics. Among bog plants, *Sphagnum* mosses are most important. Between 1865 and 1917, when industrialization progressed rapidly, bog area diminished from 91,000 ha or 910 $km^2$ (9% of the original surface) to 26,000 ha or 260 $km^2$ (2.6%). Commercial exploitation of peat stopped as late as 1992 when in the Netherlands only 1% of the original bog surface was left. Chapter 2 gives a classification of bogs dealing with the elemental hydrological, chemical and vegetational characteristics. Bog types vary along a nutrient gradient (oligotrophe, mesotrophe, eutrophe) and a pH gradient (acid, light acid, alkaline; varying from pH 2 to 8). Chapter 3 focuses on how bogs are able to keep themselves wet. If air can penetrate into the peat, decomposition of organic material occurs twenty times faster than the new peat can accumulate. Evaporation of bogs is regulated by changing the albedo (reflection) of mosses, and by changes in plant associations. The permeability and storing capacity for water is peat dependent: little decomposed peat (white peat) may contain 50% water, whereas strongly decomposed peat (black peat) could contain only 10% water. In the upper part of a bog, the *acrotelm*, plants will be in a living state and porosity is optimal. Deeper down, porosity decreases and the *cathotelm* consists of dead, little decomposed plant material. Chapter 4 addresses the impact of climate on bogs. Restoration practice is mostly a matter of letting adequate hydrological gradients return. Chapter 5 focuses on the earliest stage of bog formation in coastal and inland locations. Bogs also developed where the soil was impermeable for water, causing a “hanging” ground water level. Such a stagnating horizon might have found its origin in local geological development (presence of a riverine clay or glacial till), podsolization by accumulation of fine organic matter (humus) leading to a water stagnating horizon, or precipitation of iron in a thin layer (plastic horizon). Understanding the local cause of peat formation is relevant for adequate management and restoration. Chapters 6 and 7 show how tiny *Sphagnum* mosses are capable of building huge peatlands. Peat forming mosses are simple plants without roots, growing at the top end, while dead at the bottom side. Most of the cells of the leaves of a *Sphagnum* plant are dead and empty, and each cell has the capacity of serving as a water reservoir. As long as growth at the top overrules decay at the bottom, peat formation is proceeding. Different *Sphagnum* species have their tiny habitat range in the peat surface following local micro-relief, gradients, and regional climate. Carbon from the atmosphere is the most important material required to build a bog. The most relevant nutrients for plants, nitrogen, phosphorus and potassium, are virtually entirely relied upon through rainwater, which actually contains few of such elements. Bogs are the most nutrient-poor ecosystems in the world. The exceptionally low availability of nutrients stimulated bog plants in the process of evolution to develop fascinating adaptations along the vertical wet-dry gradient and the pH gradient to successfully survive such extreme conditions. Ericaceous species live in symbiosis with fungi of which the hyphae penetrate into the cells of the plant. Fungi make nitrogen available from dead plants, and the ericaceous plants make sugars available for the fungus in return. Chapter 8 shows the distribution of bogs in Europe. Nutrient-poor bogs mixed with nutrient-rich fens vary significantly in appearance. Peat formation requires oxygen-poor conditions, which are reached when soil is saturated with water. Therefore, a firm climatic rain surplus is necessary. More than 15 types of bogs and mixed bogs are recognized. As so many generations have left their impact on bog landscapes it is unclear if Atlantic bog landscapes were open. Trees were used for construction and for wooden roads through the peatlands. However, bogs in southern Sweden are often surrounded by pine trees and the open landscapes of the Atlantic peatlands may hint at a long-standing deforestation by humans. Recently, high atmospheric deposition of nitrogen and phosphorus stimulated birch trees to invade open bogs. Chapter 9 explains how pollen analysis in a peat core can disclose the history of the bog over thousands of years. The age of the peat layers is established by radiocarbon dating, while the assemblage of fossil pollen, fern spores and plant macro-remains tell the story of vegetation succession. Being familiar with the habitat ranges of all plant taxa involved allows reconstruction along the depth scale, reflecting the scale of time, and changes in the local to regional environments. Past climate conditions are inferred from vegetation change. Translation of tabular information into a series of scenic landscapes that follow each other in time, as seen in Figure 2, relies on skillful researchers. Such reconstructions are helpful for nature conservation agencies as managers can choose which landscape should be set as the baseline and considered to be the goal of a restoration trajectory. Chapter 10 is about the loss of peat landscapes in the Netherlands. In the second half of the 13$^{th}$ century West-Brabant massively provided peat as an energy source for the Golden Century of Brabant and Flanders. In the 15$^{th}$ century peat was commercially exploited for salt production to serve the growing fish industry. To systematically reap the economic benefits from the peatlands, colonies were developed to house the peat workers. Such villages had to be moved regularly, following wherever the site of peat digging was. Today, such villages are located at regular distance across the former peatland. Peat extraction below the water level was labour intensive. It caused lakes to grow in size, accelerated by wind action eroding the lake shores. Peat is a voluminous, but cheap product, and commercial exploitation was only possible by using bulk transport by ship. This is the reason why peatlands were first connected to larger waterways, in particular through the digging of canals. Chapter 11 points out the most important plant species making up bogs in space and time. Botanists discovered in many places unexpected remnants of a bog flora as a testimony of the lost peatlands of the past. In contrast to vegetation (chapters 9 and 11), the fauna of bogs can only be studied as far as the present is concerned (chapter 12). Still, an impression of the faunal biodiversity of bogs 500 years ago can be articulated. Human interventions and the recent high levels of nitrogen deposition diluted the extreme nutrient poor conditions. Typical animals of bogs now occurred in other proportions and some species became rare. Fauna from neighboring ecosystems could expand into the bog area, increasing faunal diversity. Most common in bogs are protozoa, bacteria, mites, various types of flies, springtails, dragonflies, bugs, beetles, lice cicada, butterflies, mosquitoes, ants and birds. In chapter 13 an explanation is put forward about the relationship between geographical characteristics of the landscape and the conditions in specific places where bogs and heathland lakes developed during the Holocene. Various local hydrological settings triggered the development of bogs and heathland lakes. It is obvious such understanding should be part of conservation and restoration practice.

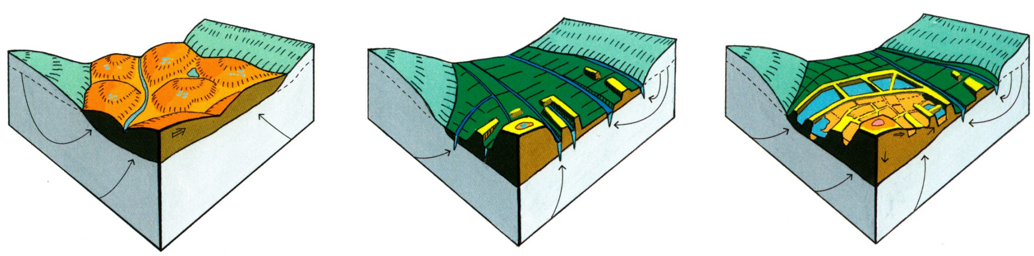

*Figure 3. Blockdiagram of the former southern part of the Boertangerveen with Zwartemeer ('Black lake') in the centre (left). After exploiting the high-quality peat, the underlying soil is mixed with the lowermost low-quality peat in reclamation activities to make the area suitable for cultivations. Only a small remnant of the historically large Boertangerveen, called Meerstalblok, remains (center). Following restoration measures, the nature reserve developed again into a coherently functioning system surrounded by a buffer zone that protects the reserve against negative impacts from surrounding agricultural land (Jansen et al. 2019, 345). Reproduced from* Hoogvenen: Landschapsecologie, behoud, beheer, herstel *with permission.*

Finally, the book considers the future of bogs, evoking the importance of nature reserves. In chapters 14 to 31 bogs are presented with a description, location on the map, cross section through the peat body, scenic photographs, and documents of past peat exploitation. The people digging up the peat mostly lived in miserable health conditions and their socio-economic status was low. Several of the small-sized bogs are little known and pop up in this book as precious small nature reserves. Eighteen bogs are presented, organized from north to south and most are located at a relatively short distance to the German border: Fochteloërveen, Witterveld, Bargerveen, Dwingelderveld, Witte Veen, Aamsveen, Wierdense Veld, Engbertsdijkvenen, Beezerveld, Haaksbergerveen, Lankheet, Mosterdveen en Besthmenerveentjes, Wooldseveen, Korenburgerveen, Groote Peel, Verheven Peel, Koningsven and the Sloping bogs near Brunssum.

This pivotal book combines a thorough presentation of stunning nature, providing a readable explanation for how rain-fed and nutrient-poor bogs function, with a systematic presentation of the last bogs preserved in the Dutch landscape. Most relevant is the view on the future of the remaining bogs. The number of photographs, schematic figures and tables amount to more than 450. The superior quality of the illustrations and the explanatory texts are wonderfully illuminating, inviting the reader to scroll through the book. Whereas the first 13 chapters draw a picture of the prevailing conditions from the time before human impact, which is the baseline, the last two chapters are most relevant in providing politicians and nature conservationists with an appreciation for what is at stake. As bogs in the northern hemisphere share so many characteristics and species, this book, with its focus on the Netherlands, is also of significance for other European and North American countries, including Canada whose bogs merit special attention and conservation efforts as well.

Natural habitats are protected by the European regulations *Natura 2000*. Currently, as few as 7.58 ha or .76 km² are determined to be "active bogs," whereas 7000 ha or 70 km² are designated as "recovering bogs." In the long run, excessive dryness and atmospheric deposition will be a major problem in conservation and restoration of bogs. However, since the 1970s hydrological measurements have shown spectacular improvements. Also, removal of trees helped to open bog areas, reducing evaporation, increasing ground water levels, and the avoidance of decaying leaves bringing too much phosphorus into the bog. Tree extraction should be repeated regularly, which stimulates the growth of *Sphagnum* mosses. As of the 1990s, expensive measures could be arranged, with bog areas divided by artificial dykes into hydrological compartments, as seen in Figures 1a and 1b. Experiments showed that groundwater levels at, or just above the surface, are optimal for the regrowth of *Sphagnum* mosses and to stimulate plant succession in the right direction. The development of a buffer zone around the remnant of peat to prevent drying is crucial; it requires the acquisition of (agricultural) land surrounding the nature reserve. Under natural conditions a bog landscape also contains nutrient-rich lags with blue-grasslands and carr. Bog landscape in the 21st century will be different from how it looked in the 18$^{th}$ to the 20$^{th}$ century. The Bargerveen (1400 ha or 14 km²) is the largest reserve but includes only a part of one original peat dome, as can be seen in Figure 3. Restoration into a complete bog landscape is not realistic. As long as precipitation shows a surplus, hydrological isolation is recovered and stabilized, and nitrogen deposition is substantially lowered, bog recovery is feasible and will continue. Measures for recovery of bogs are similar as those required for adaptation to future wetter, warmer and drier climate conditions. Such a notion provides some hope that a substantial shadow of the nearly lost bog landscapes will return during this century. This book should be present on the shelves of all nature conservation agencies. Its relatively affordable price ought to make that possible.

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