

Peatlands of Wallony (S-Belgium)

Wallonian suot (Etelä-Belgia)

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Various types of peatlands are present in Wallony: raised bogs, oligotrophic and rich fens, wet heaths, marshy woodlands. Many areas have been degraded by past and recent human activities. Much attention is now devoted to their protection, scientific study and ecological management. Besides their exceptional biological and ecological interest, they are among the last natural spaces in a very urbanised country like Belgium.

Keywords: Belgium, ecological management, peatlands, Wallony

LOCATION AND AREAS

Wallony is one of the three regions of the Belgian Federal State (Fig.1). As nature conservancy is a regional matter, only Wallony is dealt with in the present paper.

Peatlands cover 0.3 % of the area of Wallony. Peatlands of significant area occur in the Ardenne massif, delimited geologically as the region where Cambro-Ordovician and Early Devonian rocks outcrop (mainly sandstones, quartzites, slates and heterolithic quartz-bearing slates ('quartzophyllades')). The soils, loessic in origin, are leached, acidic, base-poor brown soils, often developing into rather impermeable pseudogley soils. This region is the most elevated in Belgium and therefore has a relatively severe climate (Table 1).

In comparison, the mean annual temperature and precipitation in Brussels (alt. 100 m) are 9.4°C

and 780 mm, respectively (Poncelet & Martin 1947).

All other peatlands have developed in valley depressions and are generally very small (1–5 ha); they cover some 1200 ha and are scattered over the whole of Wallony. Some of them, however, are densely grouped and/or are of particular ecological interest, notably in the Upper Semois (alt. 360 m, 260 ha), the Upper Sûre (alt. 549 m) and the Haine (alt. 40 m) valleys (Fig.1), the two latter being small in size.

VEGETATION AND FLORA ⁽¹⁾

History of the vegetation since the Late Glacial

The oldest peat deposit in the Ardenne massif has been found under the rampart of a mineral palsa

⁽¹⁾ Nomenclature following Lambinon et al. (1992) for vascular plants, Grolle (1983) for liverworts, Corley et al. (1981) and Corley and Crundwell (1991) for mosses.

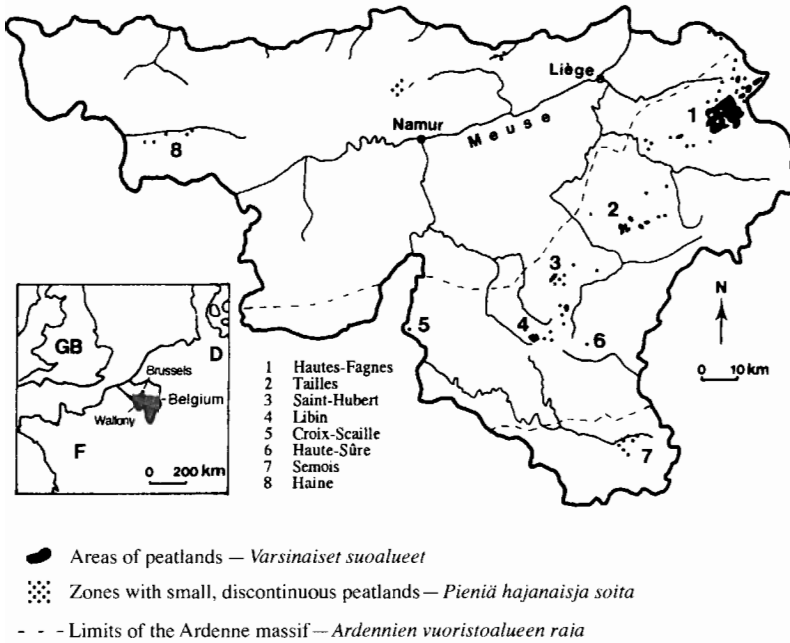


Fig. 1. Major peatlands in Wallony.

Kuva 1. Wallonian suoalueet.

remnant. Although very thin, it covers the period between Bölling (ca. 13700–12400 y. BC CAL) and Dryas III (ca. 10100–9400 y. BC CAL). The macrofossils (plants and insects) indicate a typical tundra vegetation, with numerous marshy depressions colonized by mesotrophic sedges and grasslands dominated by sedges, grasses, *Artemisia* ssp., *Selaginella selaginoides*, with scattered shrubs of *Betula nana* and *Salix* ssp. This landscape was invaded by *Pinus sylvestris* during the Alleröd up to the Dryas III, changing into an open taiga (Damblon 1996).

Peat formation started again during the Preboreal time (ca. 9700–8600 y. BC CAL) mostly inside the depressions of mineral palsa remnants (Fig. 1: areas 1 and 2; Fig. 2) and extended on large surfaces from the Boreal up to the present, above 550 m in altitude, on rather impermeable pseudogley soils. The Preboreal open forest with *Pinus*, *Betula* and *Salix* was rapidly invaded by *Corylus*, *Quercus* and *Ulmus* during the Boreal. During the Atlantic, *Ulmus* and *Tilia* grew intermixed with *Quercus* on the well-drained still base-rich loamy soils (loess), whereas *Alnus*, with *Fraxinus*, spread

Table 1. Characteristics of the five largest peatland zones on the Ardenne plateaux.

Taulukko 1. Ardennien vuoriston ylätasangoilla sijaitsevien Wallonian suurimpien suoalueiden yleistunnuksia.

Name of the plateau	Altitude of the highest point	Total area of peatlands ⁽¹⁾	Mean annual temperature	Mean temperature of January	Mean annual precipitation ⁽²⁾
<i>Ylätasangon nimi</i>	<i>Korkeimman kohdan korkeus merenpinnasta</i>	<i>Soiden kokonais-pinta-ala</i>	<i>Vuoden keskilämpötila</i>	<i>Tammikuun keskilämpötila</i>	<i>Vuoden keskisadanta</i>
Hautes-Fagnes	694 m	3750 ha	6.1 °C	-1.2 °C	1425 mm
Tailles	652 m	240 ha	6.5 °C	0°C	1300 mm
Saint-Hubert	589 m	245 ha	7.0 °C	0°C	1200 mm
Libin	569 m	140 ha	-	-	-
Croix-Scaille	505 m	90 ha	7.2 °C	-0.4 °C	> 1000 mm

⁽¹⁾ After the soil map of Belgium (IRSIA ed.)⁽²⁾ About a quarter of which falls as snow.



Fig. 2. Remnants of mineral palsas filled with peat (Hautes-Fagnes). Photo A. Drèze.

Kuva 2. Turpeen täyttämiä mineraalisten palsamuodostumien jäänteitä.

extensively on badly-drained soils. *Fagus*, already sporadically present at the end of the Atlantic, extended rapidly during the Subboreal and dominated the forest landscape on well-drained, but more and more leached soils during the Subatlantic (*Corylus*, *Tilia*, *Ulmus*, *Fraxinus* disappeared), whereas *Quercus* dominated on pseudogley soils.

These natural forests regressed rapidly ca. 800 years ago, as a consequence of the development of human settlements around the highlands. As a result of different extensive agricultural practices, the landscape was, stepwise, completely dominated by semi-natural heaths and grasslands until the turn of the 20th century. With the development of the intensive agriculture, these areas were abandoned and reforested on a very large scale, mainly with *Picea abies*, a species alien to the native flora of the Ardenne, and more recently with *Pseudotsuga menziesii*.

Outside the palsa depressions, raised bogs generally started in marshy woodlands of *Betula* and *Alnus* installed on shallow saddles ('Sattelhochmoor') or on gentle slopes ('Hanghochmoor') at the end of the Boreal or during the Atlantic. An initial oligo-mesotrophic phase with *Scheuchzeria palustris* was followed, during the Atlantic, Subboreal and Subatlantic periods, by a rapid accumulation of peat, because of the activity of peat-

mosses — first from the Sect. *Cuspidata*, then from the Sects. *Acutifolia* and *Sphagnum*, notably *S. imbricatum* and later *S. papillosum* and *S. magellanicum* — together with *Eriophorum vaginatum*.

In the centre of the main raised bogs, up to 8 m of peat accumulated within ca. 8000 y.

Human activities have deeply disturbed the active natural raised bogs, leading generally to a final degradation stage of monospecific lawns of *Molinia caerulea*.

Present vegetation

(mainly after: Schwickerath 1944, Vanden Berghen 1951, 1952, Streeel 1959, Woillard 1971, Schumacker et al. 1974, Overal 1977, Mériaux et al. 1980, Schumacker 1980, Schumacker & De Zuttere 1980, Tombal & Schumacker 1983, Fabri & Schumacker 1986, Martiny & Schumacker 1996, Frankard 1998a, Frankard 1998b).

Sloping oligotrophic fens

Most of the communities belonging to the class *Scheuchzerio-Caricetea fuscae* are secondary in

origin as a consequence of anthropogenic deforestation of marshy or peaty woodlands.

The *Carici canescens*-*Agrostidetum caninae* is the most frequent community. Besides *Sphagnum fallax*, *S. cuspidatum* and *S. teres*, *Carex canescens* and *C. echinata*, *Viola palustris* and *Epi-lobium palustre*, it offers a fairly rich flora, including some rare species such as *Dactylorhiza sphag-nicola* and *Pedicularis palustris*. Locally, under regular mowing, it tends towards a community dominated by *Juncus filiformis*.

At the margin of raised bogs or in falsa depressions, syntaxonomically badly-characterized communities such as *Carex rostrata*-*Sphagnum fallax* and *Eriophorum polystachion*-*Sphagnum fallax* communities, sometimes enriched by *Drosera rotundifolia*, and exceptionally by *D. intermedia*, *Calla palustris* or *Hammarbya paludosa*, may develop.

Very typical at resurgences of the groundwater especially at the margins of bogs, are the oligo-minerotrophic communities dominated by *Narthecium ossifragum*, an atlantic species at the eastern limit of its distribution.

Developing on anmoor soils and fed by seepage water, the *Juncetum acutiflori* sometimes extends over very large areas at the forest margins: besides *Juncus acutiflorus*, *Sphagnum fallax* and *S. palustre*, *Cirsium palustre*, *Dactylorhiza maculata* and *Polygonum bistorta* are regularly observed.

Once extensive agricultural practices have been discontinued, all these communities are rapidly invaded by dense *Salix aurita* and *S. x multinervis* scrub and eventually evolve into the potential woodland communities.

Marshy Carpathian Birch forests

Natural forests of *Betula alba* subsp. *glutinosa* (= *B. carpatica*) grow on wet soils up to 1.5 m peat thickness. *Salix aurita*, *Frangula alnus*, *Vaccinium uliginosum*, *Trientalis europaea* and many peatmosses (e.g. *S. russowii*, *S. girghensohnii* and *S. palustre*) characterize this community. Almost destroyed by human activities, only ca. 100 ha remain in Wallony.

Marshy Black Alder forests

Natural oligotrophic black alder (*Alnus glutinosa*) forests develop where water rises to the surface or in spring zones, and along brooks on anmoor or thin peaty soils. They are characterized by *Calamagrostis canescens*, *Carex laevigata*, *C. nigra*, *C. rostrata*, *Molinia caerulea*, *Cardamine pratensis* and *Lysimachia vulgaris* and an important degree of cover of many peatmosses (e.g. *S. fimbriatum* and *S. palustre*). Of this community, previously covering many hundreds of hectares, only small relict areas still exist today.

Mesotrophic to eutrophic black alder forests exhibit a more diversified field layer with *Phalaris arundinacea*, *Carex acutiformis*, *C. acuta*, *C. remota*, *C. paniculata*, *C. vesicaria*, *Phragmites australis*, *Iris pseudacorus*, occasionally with the rare *Dryopteris cristata* and *Thelypteris palustris*. They exist only locally in the Upper Semois valley.

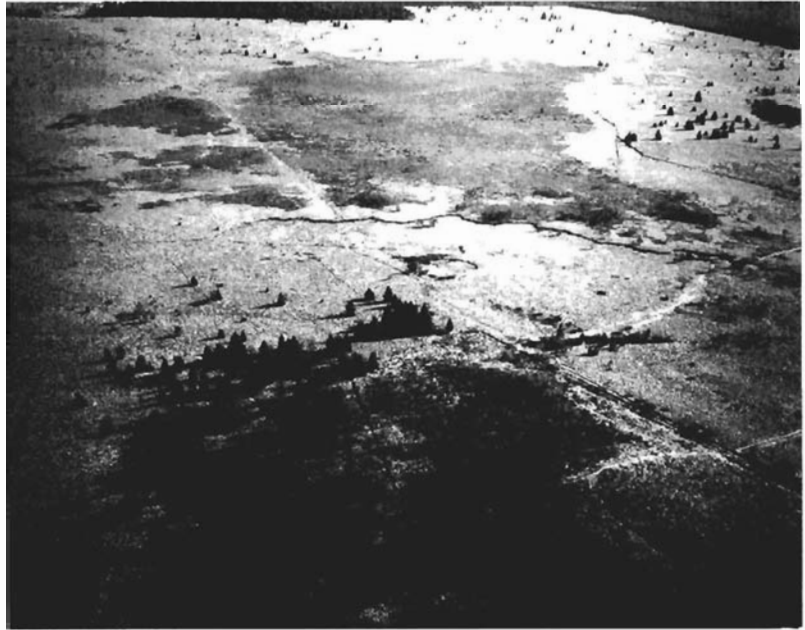
Wet heaths

Until the beginning of the century, very large areas were covered by wet heaths (*Ericetum tetralicis*). This semi-natural vegetation developed on anmoor or thin peaty soil (less than 50 cm) after the clearing of the *Betulo-Quercetum molinietsum* and extensive mowing or grazing. They are well characterized by the combination of *Erica tetralix*, *Scirpus cespitosus* subsp. *germanicus*, *Juncus squarrosus*, *Sphagnum compactum* and *S. tenellum*, often accompanied by *Gentiana pneumonanthe*, *Pedicularis sylvatica*, *Polygala serpyllifolia* and *Carex panicea*. Abandoned, they evolve rapidly into pure grassland dominated by *Molinia caerulea* and eventually return to the forest, being invaded by *Salix aurita*, *S. x multinervis*, *S. caprea*, *Populus tremula*, *Sorbus aucuparia*, *Betula pubescens* subsp. *glutinosa* and locally *Quercus robur*.

Acidic raised bogs

Raised bogs belonging to the *Vaccinio oxycocci-Sphagneteta magellanici* and to the *Eriophoro va-*

Fig. 3. The fagne Wallonne raised bog (Hautes-Fagnes). In the centre, the intact part appears darker. In the foreground, on the left, a marshy birch forest. Photo A. Drèze.



Kuva 3. Fagne Wallonne -keidassuokompleksi. Tummempi alue suon keskellä on alkuperäistä, koskematonta suota. Etualalla koivumetsää.

ginati-Sphagnetalia papilloso are optimally developed above (550–) 600 m in alt. on the Baraque-Michel (Fig. 1: area 1) and Baraque-Fraiture (Fig. 1: area 2) highlands, along the main SW–NE crest of the Ardenne massif. They formerly covered ca. 2000 ha, but today the (sub)intact parts of these raised bogs cover less than 200 ha (Fig.3).

The herb and moss layers are dominated by *Eriophorum vaginatum*, *Sphagnum magellanicum*, *S. papillosum*, and *S. rubellum* in a small 'Bulten/Schlenken' structure. The upper parts of the 'Bulten' are often densely covered by *Vaccinium oxycoccus*, *Andromeda polifolia*, *Empetrum nigrum*, *Erica tetralix*, *Calluna vulgaris* and *Polytrichum strictum*; some very local occurrences of *S. fuscum* and *Carex pauciflora* have been reported.

The 'Schlenken' initially colonized by *Drosera rotundifolia*, *Rhynchospora alba* and *Eriophorum polystachion* are rapidly invaded by *Narthecium ossifragum*.

In some parts of these raised bogs, for reasons which are not clearly understood (nitrogen depositions?, ancient fires?, slope of the bogs?), the above cited species of peatmosses are replaced by *S. fallax*, a species with larger ecological amplitude with respect to water level fluctuations and

water mineralization.

Regularly mowed and raked parts of some raised bogs give rise to a unique community looking like a wet heath with *Erica tetralix*, *Scirpus cespitosus* subsp. *germanicus* and *Juncus squarrosus* perched on 1 to 4 m of peat.

Rich fens

Today, this vegetation occurs almost only in the Upper Semois valley on Mesozoic formations and in tiny areas in the Hautes-Fagnes at some places where more mineralized water rises from the peat deposits. They often offer a mosaic of different communities with, for example, *Carex lasiocarpa*, *C. limosa*, *C. paniculata*, *C. acutiformis*, *Parnassia palustris*, *Epipactis palustris* and *Phragmites australis*. The peatmosses are poorly represented and replaced by hypnaceous mosses such as *Drepanocladus revolvens*, *D. cossonii*, *Warnstoftia exannulata* and *Homalothecium nitens* or, locally, by the very rare acrocarpous *Meesia triquetra*.

In some places along the Upper Semois valley, some alkaline peat deposits, lying on calcareous or marly soils, reach up to 3 m in thickness;

but they are interstratified with gravelly and sandy alluvial deposits probably as a result of the succession of different alkaline fens or eutrophic alder forests.

FAUNA

Insects

The peatland entomofauna is not very varied, but the species living in these sites are often rare in Belgium because some species are more or less bound to this kind of habitat. The entomologists distinguish the bog 'specialists', specifically dependent on peatlands (tyrphobiont), and the bog 'preferential' species, showing a preference for this habitat but also sometimes found in other situations (tyrphophile).

Concerning Lepidoptera, *Boloria aquilonaris* and *Coenonympha tullia* are bog 'specialists' whereas *Proclissiana eunomia*, *Clossiana selene*, *Eurodryas auriana*, *Mesoacidalia aglaga*, *Lycæna helle*, *L. hippothoe* and *Carterocephalus palaemon* are bog 'preferential' species (Keulen & Fetter 1994).

In the dragonflies there are three bog 'specialists', *Somatochlora arctica*, *Aeshna subarctica* and *Leucorrhinia dubia*, and five bog 'preferential' species, *Aeschna juncea*, *Sympetrum danae*, *Coenagrion hastulatum*, *Leucorrhinia rubicunda* and *Orthetrum coerulescens* (Barvaux 1987, Gofart 1985).

In Carabidae, *Agonum ericeti* and *Trechus rivularis* are bog 'specialists', whereas *Pterostichus rhaeticus* is a bog 'preferential' species (Deseuder 1983, Dufrière 1983). Jeuniaux (1952) mentions three Elateridae coleopters exclusive to the peatlands: *Platynichus cinereus*, *Ctenicera incanus* and *C. sjaelandicus*.

Among aquatic coleopters occurring in the peatlands, *Crenitis punctatostriata* is considered a bog 'specialist'; on the other hand, *Hydroporus melanocephalus*, *H. obscurus*, *Agabus affinis* and *Agabus congener* are classed as bog 'preferential' species (Derenne 1952, Janssens 1957).

Bog 'specialists' Diptera are represented a. o., by a stinging midge, *Culicoides impunctatus* (Goetghebuer 1952) and a tipula, *Tipula subnodicornis* (Leloup & Jacquemart 1963), whereas Ti-

pulidae Diptera *Limnophila phacostigma* and *L. squalens* are considered bog 'preferential' species (Leloup & Jacquemart 1963).

Only one ant, *Formica transkaucasica*, is typically associated with peatbogs in Belgium (Gaspar 1966).

Amphibians and reptiles

No amphibian or reptile is specifically associated with peatlands in Wallony. However, the frog (*Rana temporaria*) and the lizard (*Lacerta vivipara*), both generalist species, often occur in these habitats.

Birds

No species is strictly bound to our peatlands, although certain species living in open and more or less wet landscapes occur more frequently in this habitat in Wallony: the hen harrier (*Circus cyaneus*), the black grouse (*Tetrao tetrix*), the snipe (*Gallinago gallinago*), the short-eared owl (*Asio flammeus*), the meadow pipit (*Anthus pratensis*), the great grey shrike (*Lanius excubitor*), the red-backed shrike (*Lanius collurio*), the whinchat (*Saxicola rubetra*) and the redpoll (*Carduelis flammea*).

Among these birds, the black grouse (*Tetrao tetrix*) which is decreasing throughout western Europe, must be highlighted (Ruwet 1982) because the last viable population in Belgium and in the surrounding countries remains on the Hautes-Fagnes plateau. Nevertheless, from a maximal population of 200 males in 1972, only 36 were recorded in 1995 (Ruwet 1996).

Mammals

Some small mammals live in the peatlands but they aren't strictly associated with them. Short-tailed vole (*Microtus agrestis*) is the commonest rodent there. The most frequent insectivores are the common shrew (*Sorex 'araneus'*) and the pygmy shrew (*Sorex minutus*). Water shrew (*Neomys fodiens*) is clearly rarer (Libois 1975).

Some carnivores (e.g. *Vulpes vulpes*, *Mustela*

nivalis, *Mustela erminea*) and wild ungulates (*Cervus elaphus*, *Capreolus capreolus*, *Sus scrofa*) occur frequently in the peatlands.

HISTORICAL USE OF PEATLANDS

The Ardenne, like the neighbouring lands, suffered its first important human occupation with the Celtic invasions in the course of the first millennium BC. The first large forest clearings around the settlements and the introduction of different agropastoral practices (temporary cultivation of cereals, grazing, mowing) date from this time.

After 1000 AD, the growth in population resulted in a considerable increase in cultivated and grazed areas to the detriment of the forest. In the 16th century, deforestation reached such a degree that the firewood shortage caused more and more intense exploitation of peat bogs (Dumont 1975). Peat cutting persisted until the middle of the 20th century in the Hautes-Fagnes.

Thus the landscapes were deeply modified by a range of practices in the former agropastoral economy, including mowing, raking, deforestation, firewood cutting, charring of wood, grazing, grubbing up forest, gold panning, mattocking and turf cutting as well as by draining and since the beginning of this century by spruce forestry (Drèze & Schumacker 1997).

The main agropastoral practices in use on peatlands were mowing and raking, grubbing up forests and peat cutting. Until the beginning of this century, farmers used them to mow grasses, sedges and rushes to feed the cattle. This hay, raked with peatmosses, heather, blueberry, broom and young shrubs was also used as litter for the cattle (raking). Mixed with excrements, this litter formed manure of the highest quality (Fig. 1: area 1) (Martiny 1988).

Temporary cultivation (chiefly rye in Ardenne) was linked with grubbing up forests. The wet plots of heathlands were drained by small shallow drains about 3 m apart, with the drained materials thrown out to raise the ground to be cultivated or used for burn-beating — combustion of woody materials from abandoned heath land in a fire covered with sods of humus. This combustion provided ashes to fertilize the soil. The ridges were cultivated for one year (Froment 1968).

Some places (Fig. 1: area 1) still display traces of the balks from ploughing (Drèze & Schumacker 1997).

Practised since time immemorial (Fig. 1: areas 1, 4 and 5), the exploitation of peat for heating seriously cut into the main peatlands. Peat cutting was generally a user right, either on a familial or common basis. Locally some semi-industrial peat cutting plants were installed by Prussian authorities during World War I. The exploitation of peat required significant draining works, no doubt responsible for the destruction of parts of the bogs and a consequent monotonous growth of purple moor-grass (*Molinia caerulea*) (Drèze & Schumacker 1997).

Progressively, towards the middle of the 19th century, the traditional pastoral and agricultural practices were abandoned and a policy of reforestation of degraded forests, heaths and peatlands with conifers was developed. This large scale reforestation began around 1870, first with pine (*Pinus sylvestris*) but mainly with spruce (*Picea abies*). This tended to dry out the waterlogged soils through a drainage network system. The plantations were separated by means of fire-breaks (Fig. 1: areas 1 and 2) (Bouillenne et al. 1956, Dumont 1975). This policy also led to the regressive evolution of the spontaneous vegetation and its replacement by a *Molinia caerulea* facies (Fig. 1: areas 1 and 2, 5 and 7).

Thus human activities are responsible for the present aspect of the landscape, its diversification and its outstanding biological enrichment. Unfortunately, recent technological progress drastically changed this state of things and human activity has become ubiquitous. This confirms the necessity to protect these open semi-natural environments, not only by giving them the status of nature reserves, but above all by managing them appropriately.

PROTECTION MEASURES

Protected species

Various typical peatland plants, very uncommon or threatened in Belgium, have been legally protected since 1976: *Aconitum napellus* subsp. *lusitanicum*, *Calla palustris*, *Dactylorhiza fistulosa*,

D. incarnata, *D. maculata*, *D. sphagnicola*, *Drosera intermedia*, *D. rotundifolia*, *Epipactis palustris*, *Erica tetralix*, *Gentiana pneumonanthe*, *Hammarbya paludosa*, *Lycopodiella inundata*, *Menyanthes trifoliata*, *Osmunda regalis*, *Parnassia palustris*, *Trientalis europaea* and all *Sphagnum* species.

Three butterflies of peatlands have been protected by law since 1987: *Boloria aquilonaris*, *Lycæna helle* and *Proclossiana eunomia*.

All indigenous wild species of vertebrates living in Wallony are fully protected, except those capable of causing significant damage (law from 1983), those classified as game species (law from 1992, modifying the law of hunting) and those for which a capture license may be obtained (law from 1984).

Nature reserves

Various peatlands have been classified as State nature reserves. These reserves are managed by the agents of the Nature and Forests Administration of the Walloon Region, assisted by management commissions composed of scientific experts and representatives of local associations for nature conservation. This is the case for the largest peatland massifs: the Hautes-Fagnes plateau (ca. 4000 ha of nature reserve with more than 1000 ha of peatlands), the Tailles plateau (ca. 358 ha), the Saint-Hubert (ca. 49 ha) and Recogne (ca. 48 ha) plateau.

Many other peatlands, often small in size, are private nature reserves managed by nature associations. Some of them have obtained full recognition from the Walloon Region (approved reserves) and receive some financial and technical support for their management.

Listed sites

Two raised bogs of the Tailles plateau (ca. 42 ha) and mires of the Upper Semois valley (95 ha of eutrophic and acid fens, peaty woodlands and raised bog fragments) are listed sites in Wallony. The law protects these areas against modifications but doesn't provide means for their management.

Wet areas of biological interest

Three peatland sites without protection status (one on the Saint-Hubert plateau and two in the Upper Semois valley) have been listed in the 'Wet areas of biological interest', designated by the Walloon Region since 1989. In these sites, some protective measures for the flora and fauna are taken (protection of indigenous plants; protection of wild indigenous animals, except those classified as game species, and protection of their habitats, nests and eggs).

Forests subjected to the Forestry Code

In a recent memorandum (1997) about the management of forests subjected to the Forestry Code (State and municipality forests), the Administration of Nature and Forests lays down the following restrictions about peaty woodlands areas without protected status: it is forbidden to drain peaty soils or to afforest soils covered with more than 40 cm of peat and the immediate surroundings of springs.

International protection status

Many peatland sites have been designated as central zones of the Special Protected Areas under the application of the EU-Birds Directive 79/409/EEC. These sites will be included in the future European ecological network 'Natura 2000'.

Some peatlands have been declared as Council of Europe Biogenetic Reserves (Hautes-Fagnes, Tailles, Saint-Hubert and Recogne plateaux).

The State nature reserve of the Hautes-Fagnes has been awarded the European Diploma for Nature Conservancy by the Council of Europe since 1966.

At the last meeting of the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (Brisbane, 1996), it was suggested to the contracting parties to register some peatlands in the 'List of Wetlands of International Importance'. In 1997, the Administration of the Walloon Region proposed a new Ramsar site to the Convention, including the peatland

massif of the Hautes-Fagnes.

DEGRADATION OF RAISED BOGS: PROBLEMS AND RESEARCH ACTIVITIES

Despite legal conservation measures, the survival of peatlands is threatened by dynamic degradation processes initiated by ancient anthropogenic activities as well as by more recent factors. Most marshy woodlands, fens and heaths have been reclaimed. The areas of actively growing raised bogs have been gradually but drastically reduced over the last four centuries by mowing, raking, peat cutting, draining, afforestation and burning, and more recently by air pollution, deicing salts and tourist pressure. Only 100 ha of representative oligotrophic mires remain on the Hautes-Fagnes and 40 ha on the Tailles plateaux; elsewhere, they are relicts. This problem, and the research relating to it, are now explained briefly using the example of the Hautes-Fagnes.

Intact zones are progressively invaded by *Molinia caerulea* which leads to the disappearance of the typical peat-forming communities. Diachronic mapping and transects show the reduction of floristic diversity in detail, with regression of *Sphagnum* ssp. and *Eriophorum vaginatum*, a decrease in 'Schlenken' and expansion of dwarf shrubs, with evidence of drying (Bouillenne & Streeel 1957, Jortay & Schumacker 1989, Hindryckx et al. 1990, Frankard & Hindryckx, in press).

In order to understand the origin of these facts, the hydrological, physico-chemical and paleo-ecological factors governing the functioning of the peat-bogs are investigated.

Studies based on dip wells scattered on the bogs have shown that the lowering of the water-table in summer is significantly greater in the disturbed areas than in the intact ones. From measurements of the hydrological balance of bog catchments and of the structure of the peat, it is thought that *Molinia* plays an important role in the reinforcement of the degradation processes, owing to a deep rooting and a high transpiration rate; furthermore, it is a pyrophyte (Wastiaux et al. 1991, Wastiaux 1996).

The composition of the peat lying immediately

under the *Molinia* lawns and under intact raised bog vegetation is perceptibly different. The more the vegetation is disturbed, the higher are the humic acid concentration and the ash content. *Sphagnum* remains seem to have been destroyed after the invasion of *Molinia* (Hindryckx 1989, 1990).

Future trends in the evolution of the raised bogs in the Ardenne massif taking greenhouse effect into consideration have also been evaluated by Schumacker et al. (1996).

These results open many perspectives for future research in, for instance, the structure and imbrication of the peat constituents and macrofossils, the state of degradation of the bogs and the water retention characteristics in the different parts of the bogs. The recent evolution of vegetation will be studied by palynology. A general survey of the sub-surface topography of the main raised bogs, using ground penetrating radar, has begun in the Hautes-Fagnes.

All these data are gathered in order to conceive and to assess management measures, the aim of which would be the restoration of favourable conditions for peat-forming vegetation. Indeed, restoration measures, even if they work well elsewhere, have to be carefully adapted to the local conditions of each bog. It must also be kept in mind that the aim of conservation and restoration of peat-bogs in Belgium is not to produce peat again, but to protect these exceptional ecosystems.

THE MANAGEMENT OF PROTECTED PEATLANDS

Management of raised bogs

Since 1993, some experimental management measures have been taken in the Hautes-Fagnes nature reserve (Ghiette et al. 1995; Frankard & Ghiette 1998).

The protection of undisturbed or little-damaged areas of ombrogenous raised bogs is ensured by closing the ditches with peat dams and filling them and by removing or limiting the naturally growing trees and shrubs.

All the footpaths running on or along undamaged raised-bogs are now forbidden to walkers, because of the disastrous effects of trampling on



Fig. 4. General view of a scraped site (Hautes-Fagnes). Photo P. Ghiette.

Kuva 4. Yleisnäkymä ennallistettavalla suolla sijaisevalle koealalle, josta kasvillisuus ja ylin turvekerros on kuorittu pois.

peaty soils (destruction of rare species, destructuring of highly structured communities, mineralization of upper peat).

In the partly degraded raised bogs areas, dominated by *Molinia caerulea* and connected to remaining undamaged areas, the superficial peat layer has been scraped manually, on plots of 100 m² each, in order to remove the vegetation, the accumulated litter and the highly mineralized peat. It also restores the ground surface to a level close to the mean perched water-table (successful bog regeneration requires permanently wet conditions and wide water table fluctuations can inhibit *Sphagnum* regeneration).

The scraped surfaces are profiled with a gentle slope and a microtopography is created to offer an ecological gradient of moisture and depth favourable to the re-establishment of different peatmoss species (Fig. 4).

Various typical bog plants recolonize such scraped plots by spreading their diaspores from the intact parts of the raised bogs (Fig. 5). *Sphagnum* species, especially, appear progressively. The scraped surfaces that are more or less permanently inundated are colonized by floating *Sphagnum cuspidatum* rafts. In the soaked, frequently unflooded areas, *Sphagnum fallax* and *S. papillosum* are the most important parts of the *Sphagnum* recolonization.

These field experiments began five years ago. They seem to show that it is possible to regenerate pioneer bog plants communities and to re-

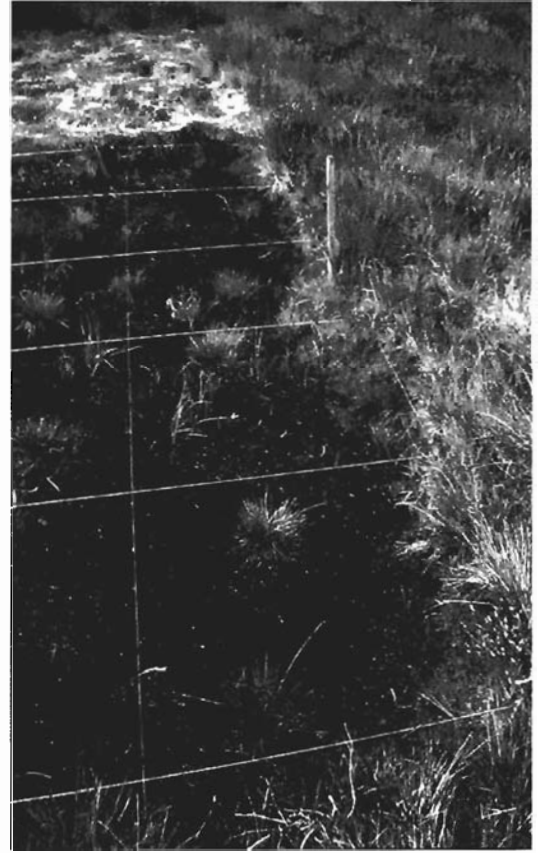


Fig. 5. Scraped site spontaneously recolonized by *Sphagnum* ssp. and *Eriophorum vaginatum* (Hautes-Fagnes). Photo P. Ghiette.

Kuva 5. Rahkasammalten (*Sphagnum* ssp.) ja tupasvillan (*Eriophorum vaginatum*) valtaama koeala, josta kasvillisuus ja ylin turvekerros oli aiemmin kuorittu pois.

initiate a process leading back to a functional peatland ecosystem. However, the regeneration process is slow.

Furthermore, the scraping might be favourable to different invertebrate species such as dragonflies.

Works inspired by management measures applied since 1983 for the renaturation of a heavily cut raised bog in the Rhön mountains (Germany) (Grosse-Brauckmann & Reimann 1989), is taking place on the fagne Wallonne raised bog (Hautes-Fagnes).

In order to reduce the lateral water drainage and to stop the erosion of the peatbog along the former exploitation scar, this latter has been pro-

filed with a ca. 15% slope. Following this, the cut-over area has been wholly remodelled in order to rewet it, by building a system of low dams of peat across the slope. The created lagoons maintain flooded areas at the bottom of the raised-bog. If conditions are favourable, they could be recolonized by fen species.

Management experiments are also tested on completely degraded peat bogs in order to try to regenerate the original moss-dominated communities.

In these strongly damaged ecosystems, *Molinia caerulea* completely dominates, often in monospecific communities, and typical bog species occur only sporadically.

The ditches are systematically dammed. Since 1993, some plots have been scraped mechanically at a few experimental sites. The experiment shows that there is no — or only very slow — recolonization without intervention on the scraped surfaces. Indeed, the exposed peat is too old to contain viable seed bank. Moreover the rarity, or the lack, of typical peat bog plants close to the experimental sites does not facilitate the introduction of their diaspores.

Fragments of *Sphagnum* species are spread on the scraped surfaces, because many studies have shown that chipping and spreading of *Sphagnum* material can lead to a re-establishment of the moss layer (Weber 1993, Money 1995, Rochefort et al. 1995, Wheeler & Shaw 1995, Campeau & Rochefort 1996, Quinty & Rochefort 1997, Rochefort & Campeau 1997). *Sphagnum cuspidatum* is introduced into flooded areas, *Sphagnum fallax* into soaked areas.

Sowing and planting of *Eriophorum vaginatum* and *E. polystachion* have also been done, because their presence accelerates an efficient re-establishment of *Sphagnum* species (reduction of evaporation from bare peat surfaces under their cover, favourable microclimates under tussocks of *Eriophorum vaginatum*, anchoring places) (Matthey 1993, 1996, Weber 1993, Grovernier et al. 1995, Sliva et al. 1997).

A varied microtopography and the presence of a ground cover (straw, for example) also create a variety of numerous suitable micro-sites where the diaspores may have a better chance of surviving and germinating (Quinty & Rochefort 1997).

Many years of observation will be needed to assess the success of this management method in

terms of the re-establishment of bog plants carpets and later, in terms of restoration of functional peatland ecosystems on completely damaged peat-bogs. If these preliminary experiments are successful, managed areas will be increased progressively.

Management of peaty woodlands

The only management measures taken for peaty woodlands concern the removal of non-indigenous species that sometimes invade them (mainly spruce) and the blocking of the ditches.

Management of wet heaths

Up to now only restricted, but representative areas of wet heaths have been managed by mowing, mattocking and grazing.

Mowing is the most employed management technique. It is easy to use, can be applied over wide areas and gives good results fairly quickly, if typical moorland species still exist on the sites or in their immediate surroundings.

Removal of a layer of topsoil (mattocking) has been tested on some experimental plots (Dumont & Champluvier 1990). Such a drastic management measure eliminates undesirable species like *Molinia caerulea* and promotes recolonization by heath species with a viable buried seed bank.

Grazing has only been tested since November 1997 in a large wet heath area of the Hautes-Fagnes nature reserve, with a flock of 230 sheep.

Management of fens

Most frequent management measures concern the removal of natural invading trees and shrubs, the restoration of hydrological processes by the blocking of ditches and mowing with appropriate machinery (Tanghe & Herremans 1990). Future management of fens by grazing is being considered.

Management of animal populations

Specific management measures are applied to some animal species. Former peat-diggings are

re-excavated for batrachians and insects, for example for the rare *Aeschna subarctica* (Tanghe & Herremans 1990, Goffart 1998).

The conservation of black grouse populations (*Tetrao tetrix*) needs different measures: mowing the lecks, preservation of the wet heaths, maintenance of some isolated trees and dispersed groves, opening of areas too densely invaded by shrubs and trees and monitoring of large areas where the public is not admitted during the breeding season (Ruwet et al. 1986).

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TIIVISTELMÄ:

Wallonian suot (Etelä-Belgia)

Walloniassa, Belgian eteläisessä, ranskankielisessä osassa, on n. 5000 ha turvemaita. Suurimmat suoalueet sijaitsevat Ardennien vuoriston korkeimmilla ylätasangoilla (yli 500 m., korkeimmat 694 m. mpy.), missä viileänpöytä ilmasto ja huonosti vettä läpäisevä ja hapan pohjamaa on luonut suotuisat olosuhteet soiden syntymiselle (kuva 1, taulukko 1). Joitakin minerotrofisia puustoisia soita ja avosointia esiintyy myös laaksoissa Ardennien ulkopuolella.

Alueen vanhin turvekerrostuma on kuvattu ajalta 13700–9400 v. eKr. (Bölling-Dryas III), mutta suurin osa nykyisistä soista on saanut alkunsa preboreaalisena aikana 9700–8600 v. eKr. Kun mineraaliaineksestä koostuneet palsamuodostumat (korkeus n. 5 m., halkaisija 50–100 m.) alkoi jättää jälkeensä sulaa, niiden keskelle muo-

dostui kraaterimainen märkä painanne, joka joutui suokasvillisuuden valtaan (kuva 2). Näistä muodostumista alkunsa saaneet suot levisivät vähitellen laajemmille alueille.

Walloniassa on yhä useita luonnontilaisia suoja suoyhdistymätyyppejä. Keidassoita on alunperin ollut n. 2000 ha, mutta niiden ala on nykyään supistunut alle 200 hehtaariin. Tyypillisen keidasoiden kasvivyhdyskunnan on muodostavat *Eriophorum vaginatum* ja *Sphagnum magellanicum* -mättäät ja *S. papillosum* ja *S. rubellum* -painanteet. Lettoja, joiden kasvillisuus koostuu useista erilaisista ruskosammaleiden luonnehtimista kasvivyhdyskunnista, esiintyy pääosin mesozooisten muodostelmien päällä, mutta myös keidasoiden alueilla lähteisillä paikoilla. Luonnontilaisia koivumetsiä (*Betula alba* subsp. *glutinosa*) kasvaa paikoit-

tellen jopa 1,5 metriä paksulla turpeella. Tervaleppäkorpia esiintyy jokilaaksoissa ym. säännöllisesti tulvivilla alueilla, joissa turvekerros on ohut ja epäyhtenäinen.

Lukuunottamatta hyönteisiä, vain muutamat eläinlajit esiintyvät ainoastaan soilla. Soita suosivia, mutta muissakin elinympäristöissä tavattavia lajeja, on kuitenkin runsaasti, esimerkkinä mainittakoon teeri (*Tetrao tetrix*).

Ihmisen toiminnalla on ollut merkittävä vaikutus soihin ja niiden kasvillisuuteen jo vuosisatojen ajan. Yhtäältä metsien raivaus laitumiksi ja maatalouskäyttöön, jota harjoitettiin vielä 1900-luvun alussa, synnytti uusia kasviyhdyskuntia: märkiä kanervanummiä (*Ericetum tetralicis*) syntyi ohuturpeisille soille voimaperäisen niiton ja laidunnuksen jälkeen ja oligotrofisia avosoita (*Scheuchzerio - Caricetea fuscae* -yhdyskunnat) taasen harkattaessa puustoisia soita. Toisaalta soiden käyttö maatalouteen (niitto, turpeen nosto) myös vahingoitti suoaluontoa. 1800-luvun puolivälissä soita alettiin metsittää voimakkaasti. Metsitykseen liittyvä ojitus ja kulutus sekä viimeaikaiset ympäristöongelmat kuten ilman ja veden saastuminen sekä matkailu, ovat osaltaan vähentäneet luonnontilaisen soiden alaa.

Viime aikoina suoaluontoa on alettu suojella lainsäädännöllisin keinoin. Lähes kaikki suurimmat suoalueet ovat kansallisia luonnonpuistoja tai luonnonsuojelualueita; osa alueista on myös kan-

sainvälisten suojelusopimusten piirissä.

Valitettavasti pelkkä soiden rauhoitus lainsäädännöllisin keinoin ei riitä: alkuperäisen suoaluonnon suojelemiseksi tarvitaan aktiivista tieteelliseen tutkimukseen perustuvaa suunnittelua ja käytännön toimintaa. Alle 200 ha koskematonta keidas-suoaluontoa on enää jäljellä. Suurin osa suoalasta on siniheinän (*Molinia caerulea*) valloittamaa ja sen leviäminen kohti soiden keskustaa jatkuu yhä. Yksityiskohtaisia tutkimuksia on tehty mm. kasvillisuuden dynamiikasta sekä suoekosysteemin toimintaan vaikuttavista hydrologisista, fysiko-kemiallisista ja paleo-ekologisista tekijöistä. Tutkimustietoa tarvitaan, jotta suot voidaan palauttaa luonnontilaan turvetta muodostavine kasviyhdyskuntineen.

Suon palauttaminen luonnontilaan aloitetaan vähentämällä häiriötekijöitä ja nostamalla vedenpintaa suolle ominaiselle tasolle. Ojat padotaan, puusto poistetaan ja soilla kävely kielletään. Keidassoilla voidaan koeluentoisesti kuoria pois suolle sekundäärisesti syntynyt kasvillisuus (esim. *Molinia*) sekä sen alainen maatumempi ja ravinteikkaampi turvekerros, jotta alkuperäinen suolajisto voisi helpommin palautua alueelle (kuvat 4 ja 5). Siniheinäistyneitä kanervanummiä niitetään ja laidunnetaan alkuperäisen nummilajiston palauttamiseksi. Myös joidenkin eläinten vaatimia erityisiä elinympäristöjä pyritään säilyttämään ja luomaan uudelleen.

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