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NATURA 2000

MANAGEMENT of Natura 2000 habitats
Luzulo-Fagetum beech forests
9110

Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

EUROPEAN COMMISSION

environment

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Luzulo-Fagetum beech forest, Söderåsens nationalpark, Sweden.
Photo: Oddvar Fiskesjö

91- Forest of temperate Europe

EUNIS Classification:

G1.61 - Medio-European acidophilous forests

Summary

Luzulo-Fagetum is one of the most widespread habitat types in Central and Northern Europe. It occurs mostly in continental areas, typically on acid and nutrient-poor soils. This type of forest is dominated by *Fagus sylvatica* (beech) with *Quercus petraea* (sessile oak) at collinear level and *Abies alba* (silver fir) and/or *Picea abies* (spruce) in mountainous areas.

It ranges from plains to hills on lowlands and from sub-mountainous to high-mountainous levels on uplands. Owing to the dense shadow cast by beech, the understory is sparse and the floral diversity rather poor. The presence of decaying and dead wood is an important indicator of habitat quality, providing shelter for numerous saproxylic beetles, birds, bats and mosses listed in Annex II or IV of the Habitats Directive.

Within the general European context, management of *Luzulo-Fagetum* beech forest may be linked to several strategic issues, such as natural regeneration, recovery of typical species, diversification of both horizontal and vertical structures, encouraging species diversity, i.e. mixed stands, precautions regarding infrastructures, specific biodiversity measures, e.g. maintaining dead wood, etc.

Faced with threat of afforestation with non-native trees, the guidelines focus on favouring indigenous species, local ecotypes and rare tree species and mixed species stands. As regards structure, it is advisable to maintain heterogeneity (vertical and horizontal) and good connectivity for species with low dispersal capability. On a landscape scale, it is advisable to have several regimes (reserves, coppices, even-aged stands, uneven-aged stands) in a mosaic, which could be achieved by creating more small cutting and regeneration areas.

It is advisable to develop microhabitats, such as mega-trees and old trees, and decaying or dead wood to increase forest biodiversity and provide suitable habitat for species of European interest. Depending on the Member State, recommended volume of decaying or dead wood on a forest stand and distribution within the forest may differ.

Other guidelines are also proposed regarding the management of ungulates, glades and ponds, roads and tracks, etc.

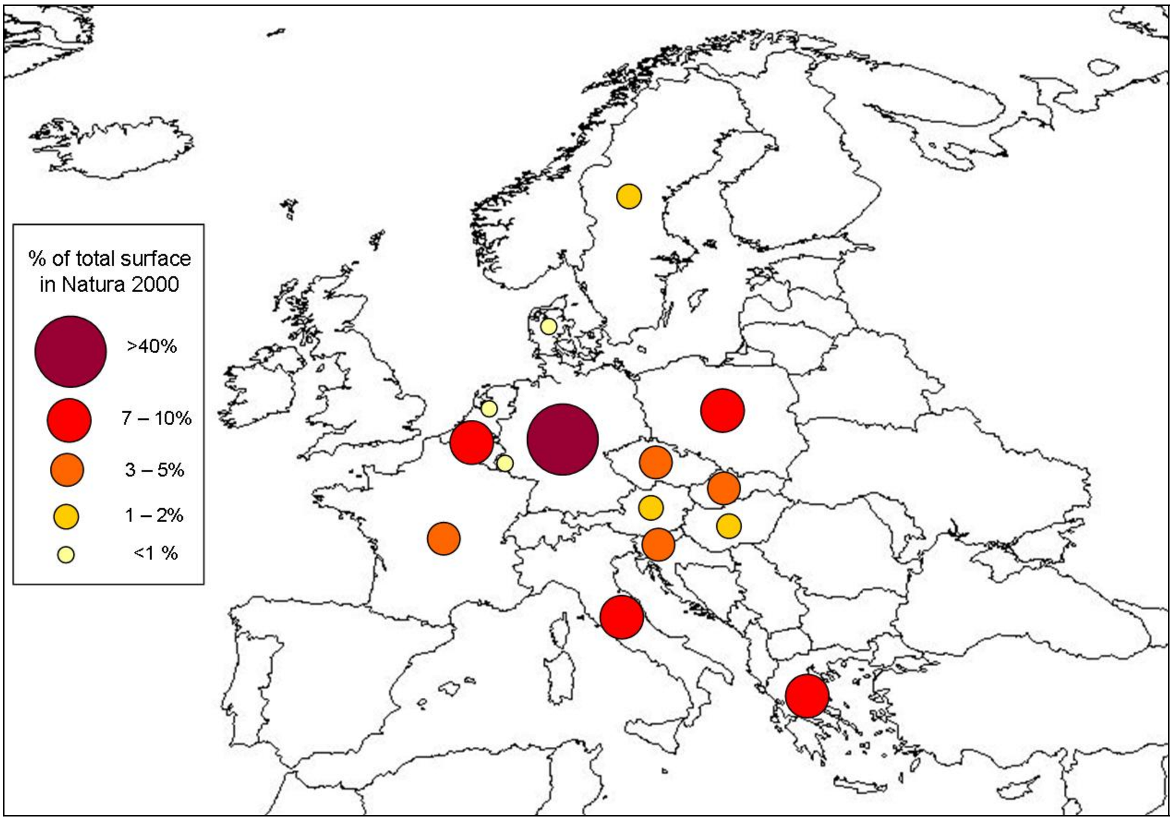
1. Description of habitat and related species

Luzulo-Fagetum beech forests occur mostly in continental areas, on acid and nutrient-poor soils. The forest canopy is dominated by *Fagus sylvatica* (beech) with *Quercus petraea* (sessile oak) on lowland levels and *Abies alba* (silver fir) and/or *Picea abies* (spruce) on mountainous areas (European Commission 2007a). Other tree species may be present depending on altitude, exposure, soil acidity, humidity and management: (e.g. *Quercus robur, Betula pendula, Acer pseudoplatanus)*. The understory of this type of forest is sparse and floral diversity rather poor. *Luzulo-Fagetum* beech forests provide habitats for numerous species of European value (insects, woodpeckers, bats, etc.) especially within decaying wood, cavities and fissures.

Distribution

Luzulo-Fagetum beech forest habitat is distributed in the mid-European domain of Central and Northern Europe, from plains to lowland hills and from sub-mountainous to high-mountain levels. The area extends from the Spanish Pyrenees in south-western Europe to the Baltic States and Sweden in the North (European Commission 2007a, Ellmauer 2005). It occurs mainly in old or recent mountainous ranges such as the Black Forest, Bavarian Plateau, the Alps, Carpathians, Ardennes, Vosges, Massif Central, Jura, Pannonic Hills and Bohemian Quadrangle. In Denmark, southern Sweden and northern Germany, it is also found on lowland hilly landscapes.

Luzulo-Fagetum beech forests occur in 17 Member States (including Romania and Bulgaria) and in 6 of the 9 biogeographical regions, being better represented in the Continental one.



Percentage distribution of the total surface of Luzulo-Fagetum beech forests in Natura 2000

Luzulo-Fagetum beech forests in Natura 2000 sites

The following data have been extracted from the Natura 2000 Network database, elaborated by the European Commission with data updated on December 2006. The surface was estimated on the basis of the habitat cover indicated for each protected site and should be considered only as indicative of the habitat surface included in Natura 2000.

Biogeographical region	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Continental	1.469	384,823	70.48
Alpine	147	77,731	14.23
Mediterranean	41	61,150	11.20
Pannonic	17	11,619	2.13
Atlantic	164	9,092	1.66
Boreal	98	1,651	0.30
Countries	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Germany	1,159	237,146	43.63
Greece	22	55,001	10.07
Poland	47	43,084	7.89
Italy	108	41,581	7.62
Belgium	118	40,040	7.33
Slovakia	58	27,111	5.14
France	54	24,469	4.49
Czech Republic	48	24,062	4.41
Slovenia	23	19,165	3.50
Hungary	15	11,379	2.08
Austria	27	7,082	1.30
Sweden	200	5,485	1.00
Luxembourg	22	4,774	0.87
Denmark	34	3,662	0.67
Netherlands	1	25	0.01
TOTAL	**1,936**	**546,066**	**100**

Main habitat features, ecology and variability

Luzulo-Fagetum beech habitat has to be placed in the general context of forests of European value. Within the Annex I of the Habitats Directive, an introductory paragraph gives some indications on specific features for all the forest habitats: *"(Sub)natural woodland vegetation comprising native species forming forests of tall trees, with typical undergrowth, and meeting the following criteria: rare or residual, and/or hosting species of Community interest."* Apart from exceptional circumstances (e.g. in the Netherlands), the criterion rare or residual is not adapted to *Luzulo-Fagetum* as it is one of the most widespread habitat types in central and northern Europe. The occurrence of species from the Annex II and IV of the Habitats Directive and from the Annex I of the Birds Directive is an important issue as well as vegetation composition and forest physiognomy and structure.

Other indicative criteria were proposed by a Scientific Working Group in 1993 (European Commission 2007a), e.g. forest with a high degree of naturalness, presence of old and dead trees, forests covering a substantial area, forests that have benefited from continuous sustainable management over a significant period.

In its natural distribution area, *Luzulo-Fagetum* beech forest is an end stage of plant succession (Ellmauer 2005). However, given that primeval forests are really rare in the EU, except for exceptional situations such as high mountains or very localised areas, the *Luzulo-Fagetum* beech forests considered here are managed. The level of man-made modifications compared to the potential natural habitat is much more at stake than for other habitat e.g. pastoral land. Forests with a high degree of naturalness, frequently associated with the various concepts of "protected forest" (Latham & Frank 2005), will not be broached in these management guidelines, which are dedicated to active management only.

Due to the dense shadow cast by beech, the understory of this type of forest is sparse and floral diversity rather poor. It may include *Ilex aquifolium, Taxus baccata* and, in managed beech forests, *Frangula alnus, Sorbus aucuparia* and *Corylus avelana,* which are not sufficiently shade-tolerant to survive in unmanaged beech forests. Vegetation clearance and treatment also often limit this understory.

In southern Sweden and Denmark the ground vegetation is characterized by an abundance of acidophilus (acid-loving) species such as *Deschampsia flexuosa* (wavy hair-grass) and *Luzula luzuloides* (white wood-rush) or *Luzula pilosa*, (hairy wood-rush). Slow litter decomposition encourages the growth of mosses and fungi development, with *Polytrichum formosum* or *Leucobryum glaucum* (Rameau *et al.* 2000, Ellmauer 2005).

According to Bus de Warnaffe & Devillez (2002), forest biodiversity is considered to consist of three dimensions: composition, structure and functioning. In terms of structure and functioning, the *Luzulo-Fagetum* beech forest description refers to spatio-temporal ecological concepts relating to forest in general and requires the following considerations:

- Differentiation regarding two spatial scales: a local scale (parcels and forestry operation level) with daily or annual integration in forestry of measures in favour of species and habitats, and a forest massif scale (planning level), which takes into account global ecological quality (Bus de Warnaffe & Devillez 2002). A third scale could be added: biogeographical level where conservation status has to be favourable.
- Forest ecosystem dynamics (temporal scale): plant succession and natural or manmade disturbance create an irregular spatial mosaic of successional habitats within the forest, representing the metaclimax.
- Features of several forest development stages: youth (mainly vertical growth and volume increasing of young trees with carbon sink); maturity (growth in thickness and breadth); and old age (decaying phase, veteran trees, deadwood). All phases are essential parts of forest structure, including old age and its specific and high biodiversity (Gilg 2005).
- The management system induced by human action (i.e. tall stands with even-aged or uneven-aged trees, coppices, coppice-with-standards, selection cutting, etc.). The Habitats Directive includes only tall native trees with typical undergrowth (at forest massif scale rather than parcel scale).

Ecological requirements

The optimal distribution of *Luzulo-Fagetum* beech forests occurs in continental rainfall-rich regions (Ellmauer 2005). This distribution is limited by soil conditions with the lack of oxygen during the growing period being due to soil wetness or instability. The lack of rainfall for several weeks in the growing period is another limiting factor. In Palatinate, beech occurs on extremely poor podzols on Triassic sandstones and the scarcity of nutrients is sometimes cited as a limiting factor (FUSAGx/GF 2004). This habitat occurs from sea level up to 1300 meters (Ellmauer 2005) in different topographical situations: plateaux, diverse exposed sides or depressions (Rameau *et al.* 2000).

The habitat grows on diverse siliceous geological substrates: granite, sandstone, gneiss, silex loam (Bensettiti *et al.* 2001). It seems to occur very seldom on limestone (Ellenberg 1986 *in* Ellmauer 2005). *Luzulo-Fagetum* beech forests are typical in acid to strong acid soils (e.g. brown soils or luvisols - Ellmauer 2005). They mostly develop on moder or mullmoder humus types, but at scarped or windy sites they are found on duff or on absent humus layers (Ellmauer 2005).

Main subtypes identified

The two following sub-types are included in the Interpretation Manual (EC 2007a):

<u>41.111 Medio-European collinar woodrush beech forests</u>
Acidophilous *Fagus sylvatica* forests of the lesser Hercynian ranges and Lorraine, at collinar level of the greater Hercynian ranges, the Jura and the Alpine periphery, of the western sub-Pannonic and the intra-Pannonic hills, not or little accompanied by self-sown conifers, and generally with an admixture of *Quercus petraea*, or in some cases *Quercus robur*, in the canopy.

41.112 Medio-European montane wood rush beech forests

Acidophilous forests of *Fagus sylvatica*, *Fagus sylvatica* and *Abies alba* or *Fagus sylvatica*, *Abies alba* and *Picea abies* of the montane and high-montane levels of the greater Hercynian ranges, from the Vosges and the Black Forest to the Bohemian Quadrangle, the Jura, the Alps, the Carpathians and the Bavarian Plateau.

These sub-types imply a large diversity of types of local stations and even biogeographical or altitudinal types (BLU & BLW 2004). Beech forest classification at European scale can be grasped by different approaches: trophic status, mesophytic to thermophilous character, geographical variants and altitudinal range (EEA 2006) and species composition. Considering national bibliographies from different countries, we will adopt a description based on both altitudinal and biogeographical types, in agreement with EEA subtypes.

Sub-atlantic submountainous beech forest

According to EEA (2006) and BLU & BLW (2007), a sub-Atlantic beech forest type can be differentiated. EEA (2006) does not differentiate in the following description *Luzulo-Fagetum* forest with *Asperulo-Fagetum* forest. It spreads from central/western Germany to Belgium through western and central France. The climatic effects of the Atlantic are less pronounced, so these forests represent a transition from the Atlantic to Central European province. Species composition in the western part is more similar to Atlantic type, whereas in the north-eastern part, species composition is very similar to that of acid or mesotrophic central European beech forest (EEA 2006).

Hill oak-beech forest with *Luzula luzuloides*

Below 500-600 meters above the sea level, stands dominated by *Fagus sylvatica* and *Quercus petraea* (sessile oak) develop in different topographical situations (plateau, diverse exposed sides or depressions). The litter is composed of entire or fragmented leaves. The sparse shrub layer comprises F*rangula alnus, Sorbus aucuparia* and *Corylus avellana* (rare in undisturbed beech forest).

Characteristic species: *Luzula luzuloides (Luzula pilosa* in Scandinavia*), Luzula sylvatica, Deschampsia flexuosa, Carex pilulifera, Vaccinium myrtillus, Festuca altissima, Maianthemum bifolium, Melampyrum pratense, Carex pilulifera, Polytrichum formosum, Leucobryum glaucum* (Bensettiti *et al.* 2001, Rameau *et al.* 2000, Naturvårdsverket 1997).

Sub-mountainous and mountainous fir-beech forest

At sub-mountainous level 500-900 metres above the sea level, the upper tree stratum is dominated by *Abies alba* (fir) and *Fagus sylvatica* (beech). The following tree species *Betula pendula, Acer pseudoplatanus, Sorbus acuparia* also occur. The shrub layer is species- poor (*Sambucus racemosa, Lonicera nigra, Rubus idaeus*). The muscinal stratum often cover a large part of the place with a predominance of *Rhytidiadelphus loreus.* A cool variant on depressions or north-facing slopes is characterized by fern growth: *Phegopteris connectilis, Oreopteris limbosperma, Dryopteris dilatata, Athyrium filix-femina.*

Characteristic species: *Luzula luzuloides, Prenanthes purpurea, Senecio fuchsii, Maianthemum bifolium, Galium saxatile, Polygonum verticillatum, Vaccinium myrtillus, Deschampsia flexuosa, Carex pilulifera, Luzula sylvatica, Polytrichum formosum, Leucobryum glaucum* (Bensettiti *et al.* 2001, Rameau *et al.* 2000)

High-mountainous continental/alpine fir-beech-spruce forests

High mountainous beech forest is defined by the altitudinal range of distribution (900 and 1300 m), by the dominance of *Fagus* and by the presence of conifers *Abies alba* and *Picea abies*. The overall structure and appearance of the stand is similar to that of the mountainous-submountainous type.

Characteristic species: *Polygonum verticillatum, Polygonum bistorta, Lysimachia nemorum, Prenanthes purpurea, Calamagrostis arundinacea, Luzula luzuloides, Senecio fuchsii, Luzula sylvatica, Galium saxatile, Vaccinium myrtillus, Deschampsia flexuosa, Carex pilulifera, Polytrichum formosum, Rhytidiadelphus loreus* (Bensettiti *et al.* 2001, Rameau *et al.* 2000).

Carpathian fir-beech forest

This type develops in the Carpathian area on compact soils characterized by higher humidity and low aeration rate. These features condition the dominance of *Abies alba* in the canopy. *Acer pseudoplatanus*, *Fagus sylvatica* and *Acer pseudoplatanus* are the main associated tree species.

Characteristic species: *Athyrium filix-femina, Circaea alpine, Dryopteris dilatata, Galium rotundifolium, Hieracium murorum, Luzula luzulina, Oxalis acetosella, Petasites albus, Rubus hirtus, Stellaria nemorum, Vaccinium myrtillus, Veronica officinalis, Atrichum undulatum, Dicranum scoparium, Plagiomnium affine, Polytrichastrum formosum* (Holeksa & Szwagrzyk 2004)

Within the different types, Rameau *et al.* (2000) differentiates variations depending on soil acidity: a fairly acidophilus (acid-tolerant) variant (optimum of white wood-rush development), an acidophilus variant with *Deschampsia flexuosa* (wavy hair-grass) and a very acidophilus variant with *Vaccinium myrtillus* (blueberry).

The central position of people in forest management induces a positive selection of species. By choosing the principal tree species, management has largely modified the tree layer with a transformation of climax beech forest into oak or oak-hornbeam forest, often called "substitute forest". In most cases, the underground vegetation remains typical of *Luzulo-Fagetum* beech forest, and this substitute habitat is easily reversible. This native, but not beech-dominated, forest type can be considered as a facies or sub-type of *Luzulo-Fagetum* beech forest. On the basis of scientific criteria, the Walloon region regards it as an integral part of Natura 2000 Habitat 9110 (FUSAGx/GF 2004). The German Bavarian land (BLU & BLW 2004) only considers as Natura 2000 habitat the original or sub-natural forests and substitute forests if they are natural enough, i.e. if the ground vegetation of an oak substitution forest is typical of *Luzulo-Fagetum*, it is mapped as such. Only those with tree layer comprising at least 50% of natural tree species are mapped. In a letter to Belgium in 2007, the European Commission opted for a broad interpretation, allowing the Members States to decide and explaining that Articles 4 and 6 apply to altered or damaged forms of habitats, too, especially if they can be restored.

Degradation of the *Luzulo-Fagetum* habitat may be linked to the level of occurrence of non-native species, but there is no set threshold. According to the German Bavarian land (BLU & BLW 2004), hill level is characterised by a natural predominance of deciduous trees, conifer presence always being due to human action: only forest comprising at least 50% of deciduous trees is considered as Natura 2000 habitat. Likewise, in mountainous areas, spruce is present naturally, and resin-rich forests are typical of *Luzulo-Fagetum* beech forest and considered as such: the canopy should comprise at least 50% beech-fir-spruce. In Luxembourg (TR-Engineering 2004), within the hill sub-type, evaluation of the conservation status of this habitat is partly based on the cover of *Fagus sylvatica* (from very good if >75 %, to deficient if <50%) and on the cover of non-typical species (from very good if <5 %, to deficient if >25%). As regards Sweden, the recently revised national interpretation sets a minimum limit of 50% coverage of beech and allows for only insignificant elements of coniferous trees (spruce < 5%). Other thresholds or methodologies can be applied by the Member States.

Species that depend on the habitat

In Central Europe, *Luzulo-Fagetum* beech forests constitute a potential habitat for several large carnivores, e.g. *Canis lupus* (wolf), *Lynx lynx* (Eurasian lynx) and U*rsus arctos* (brown bear). However, management issues for these species are currently not directly linked to forestry apart from infrastructure development in forest areas.

According to Butler *et al.* (2002), some charismatic vertebrates, e.g. woodpeckers, owls and bats, are associated with decaying wood habitat, cavities and fissures in old trees. In beech forests, this includes several species of the Annex I of the Birds Directive (*Aegolius funereus, Glaucidium passerinum, Dryocopus martius, Picus canus, Dendrocopus medius, D. leucotos, Ficedula parva and F.albicollis*) and some bats species, e.g. *Myotis bechsteinii* and *Barbastella barbastella* (Bensettiti *et al.* 2002, Müller-Kroehling *et al.* 2006).

The bats roost in fissures in old *Fagus* or *Quercus* trees or in woodpecker holes and their survival depends on preserving old and decaying trees (Rameau *et al.* 2000). Bats hunt in deciduous beech forest (e.g. *Myotis myotis*) because they contain a high diversity of insects (e.g. *Barbastella barbastella,* which feeds on small moths).

In Central Europe, *Luzulo-Fagetum* beech forests provide habitats for other Annex I bird species, e.g. nesting sites for several birds of prey or *Ciconia nigra*, dense undergrowth in mixed forests for *Bonasa bonasia;* heterogeneous forests with a dense ground vegetation of *Vaccinium* species under a light canopy for *Tetrao urogallus*; regeneration cuts (with *Betula* spp. or clear oak stands in the surroundings) for *Caprimulgus europaeus,* etc. although none of these bird species use this habitat exclusively.

Some other vertebrate species are linked to microhabitats included within the forest, as is the case of *Bombina variegata* (yellow-bellied toad) in non-shaded temporary pools or even in water-filled wheel ruts.

Luzulo-Fagetum beech forests also hold several different saproxylic[1] beetles including:

- *Rosalia alpina* (Rosalia longicorn), widespread in Europe on mountainous and lowland areas where beech is considered to be the principal host plant of its larva (Rameau *et al.* 2000).
- *Lucanus cervus* (stag beetle) adults live on trunks and branches of old trees, principally oak. The larvae live in decaying wood, often in roots and stumps.
- *Cerambyx cerdo*, another beetle from Annex II of the Habitats Directive, occurs mainly in decaying oak branches.
- *Limoniscus violaceus (*violet click beetle*)* and *Osmoderma eremita* (hermit beetle) are linked to cavities of deciduous trees as beech or oak. The first one is linked to the basal cavities of particularly old-growth forests (Bensettiti *et al.* 2002). The second one uses large cavities in old-growth forests or substitute habitats such as old hedges or even orchards.

These species were included in the Annexes of the Bern Convention and the Habitats Directive because of their conservation status and for being easy to identify and quite familiar to the public (Brustel 2001). They are key examples linked to old and decaying wood; in France alone there are over 1,900 saproxylic beetle species. Indeed, the biodiversity of decaying wood includes numerous species of insects, mosses and fungi.

Old trees within the *Luzulo-Fagetum* beech forest constitute a potential habitat for rare moss species listed in Annex II of the Habitats Directive: *Buxbaumia viridis, Dicranum viride* (Bensettiti *et al.* 2002), *Scapania massalongi, Tayloria rudolphiana, Orthotrichum rogeri (*Müller-Kroehling 2006). Several fungi threatened Europe wide occur in beech forests: *Hericium erinaceum, Phylloporus pelletieri* and *Podocypha multizonata* are directly linked to old deciduous trees (*Fagus* or *Quercus*) and threatened due to cutting for safety reasons and intensive forest use (Dahlberg & Croneborg. 2003).

In southern Sweden, a minimum of four typical lichen species, such as *Catinaria laureri, Chaenotheca brachypoda, Chaenotheca chlorella, Lecanora glabrata, Lobaria pulmonaria, Lobaria virens* or *Pyrenula nitida,* should occur on at least 50% of trees for it to be regarded as having favourable conservation status (Naturvårdsverket 2005).

Related habitats

There are three main categories of habitats related to *Luzulo-Fagetum* beech forest: other forest types, plant succession mosaics and other forest habitats.

Luzulo-Fagetum forest may appear in contact with other forest types (91E0*, 9180*) in some specific conditions, e.g. alluvial areas, slopes. The transitions involved in the three following habitats need further precision:

- The transition between *Asperulo-Fagetum* beech forests (9130) and *Luzulo-Fagetum* beech forests (9110) is continuous. Both have similar management requirements (TR-Engineering 2004, BLU & LWF Bayern 2004, EEA 2006). The main differences are linked to the type of soil (acidophilus moder versus calcareous mull) and typical species e.g. *Asperula odorata* and *Melica uniflora*. A phytosociological (classification based on floristic considerations) transition type seems to exist (TR-Engineering 2004).
- In mountainous areas, the transition between acidophilus *Picea* forests of the mountainous to alpine levels (*Vaccinio-Piceetea* (9410)) and *Luzulo-Fagetum* beech forests (9110) is linked to climatic conditions (soil humidity, temperature).

[1] Species of invertebrates that are dependent, during some part of their life cycle, upon the dead or dying wood of moribund or dead trees (standing or fallen), or upon wood-inhabiting fungi, or upon the presence of other saproxylics. From Speight, 1989.

- In colluvial or alluvial deposits with regularly humid soils (TR-Engineering 2004), *Luzulo-Fagetum* beech forest is replaced by the sub-Atlantic and medio-European oak or oak-hornbeam forest of *Carpinion betuli* (9160)
- On very acid podzolized and hydromorphic soils, habitat 9190 (old acidophilous oak woods with *Quercus robur* on sandy plains) is also found in contact with *Luzulo-Fagetum* beech forests (Patrick Verté pers. comm.).
- In Sweden, beech forest with ground vegetation significantly affected by grazing (on-going or recently ceased) is classified as Fennoscandian wooded pastures (9070).

On a massif scale, forest is composed of numerous juxtaposed habitats, building a complex mosaic. The *Luzulo-Fagetum* beech forest, final stage of plant succession in the ecological conditions described above, is closely related to other vegetation dynamic stages (Rameau *et al.* 2000):

- Gap vegetation (windfall, cutting): the herbaceous layer is composed of *Digitalis purpurea*, *Epilobium angustifolium* and *Sambucus racemosa*.
- Forest hedges with shrub vegetation and *Pteridium aquilinum*,
- *Vaccinium*, *Calluna* or *Genista* heaths
- Pre-forestry meadows with *Deschampsia flexuosa*, *Holcus lanatus, Agrostis capillaris, Nardus stricta*.

Finally, other habitats appear in mosaic with *Luzulo-Fagetum* forest, without dynamic links. They may be other Annex I habitats as bogs (7110*, 7140*), screes and rocky slopes (8110, 8220) or some species habitats such as ponds or both categories as rivers. For vegetation mapping purposes (TR-Engineering 2004) or administrative grant schemes (Thauront *et al.* 2003), a minimum surface between 1000 m^2 and 1500 m^2 was identified to consider these habitats as part of the forest or specific entities.

Ecological services and benefits of the habitat

Whilst maintaining traditional productive and economic functions, such as timber production and game shooting, efforts should be made to achieve complete fulfilment of the additional functions of various forest habitats (European Commission 2006). Besides biodiversity maintenance, they are:

- Protective functions: protecting site, drinking water and air. Ecosystemic services comprise protection of the following: landscape from fluctuating water runoff; water quality in water streams and reservoirs; abundance and quality of water sources. Soil protection services protect soil from water and wind erosion, bank erosion, landslides and avalanches. Air protection covers the impact of the forest on air quality and pollution by solid and gaseous matter (e.g. CO2, NOx, etc.) also influencing climatic change (Sisak 2004);

- Carbon sink function: forests can sequester substantial amounts of carbon; they have an important role in improving the global carbon balance and helping to create renewable alternatives to the consumption of fossil fuels and other non-renewable materials (Ballu 2006). In this way, they mitigate the effects of climate change.

- Social and cultural functions: recreation and tourism, landscape amenities, sports, hunting, non-timber forest products, health promotion, education and research and cultural identity.

Trends

The current status of European forests is linked to a combination of two key parameters (Falinski & Mortiner 1996): the postglacial recovery (± 10 000 years ago) conditioned by climatic and soil factors, and the influence of human settlement since the Neolithic era. Some large herbivores and carnivores disappeared since a while from most European beech forests, e.g. *Bison bonasus* (European bison).

According to European Commission 2003a, forests "*have had a fundamental importance as a basic resource for the progress of human settlement and for the creation of a civilised and prosperous Europe*". The marks of human clearings for cultivation or firewood have been ongoing for at least 2000 years; however, the forest colonized again (Ballu 2006) in hard times, and several current forests used to be pastoral or cultivated land (FUSAGx/GF 2004).

At other times, e.g. 18th and 19th centuries, overexploitation involved coppices with very short cutting cycles being developed to respond to the need for energy resources. Furthermore, various local "user rights" reinforced forest impoverishment. National policies have sometimes driven reforestation, as, for example, in France after 1862, with hundreds of thousand hectares afforested (Ballu 2006). The main objectives were the fast and efficient production of timber to supply growing markets and protection against erosion. This led to the establishment of conifer monocultures (European Commission 2003b). All these trends also apply to Continental forests where *Luzulo-Fagetum* beech forests predominate.

In recent decades, forest habitats have been changing due to more intense management, an increase in uniformity, fragmentation, use of exotic tree species, introduction or maintenance of animal species for hunting, drainage and air pollution (European Commission 2003a). Again, this also applies to *Luzulo-Fagetum* beech forests which were intensively planted with *Picea abies* and other conifers, e.g. *Pinus sylvestris, Pseudotsuga menziesii*) over the last 50 years. Other stands suffered qualitative deterioration due to species selection (FUSAGx/GF 2004) or coniferous enrichment (Ellmauer 2005). However, the surface area of *Luzulo-Fagetum* beech forest has tended to increase due to the abandonment of grassland surfaces (Bensettiti *et al.* 2001). Some other changes in biodiversity are probably due to the disappearance of large carnivores and to deer density increasing the impact on composition of flora species (Rooney *et al.* 2004).

Although the first forest sustainable management legislation dates from 1340 in France (Ballu 2006), it was only in the 19th century that forestry became a scientific profession, with higher education for foresters spreading across Europe (European Commission 2003b). Since then, planning and improvement of sustainable development concepts have increased continuously, e.g. the Ministerial Conferences on the Protection of Forests in Europe (MCPFE) have adopted several resolutions to define and apply these concepts. Over the last twenty years, conservation and enhancement of biological diversity have become a critical issue in forest management. According to EEA (2006), so-called nature-oriented forestry is currently the main trend in European forestry. It is based on somewhat less intensive management methods favouring retaining trees and decaying wood, the establishment of natural tree species and a species mix, as well as protection of small key biotopes.

The eco-certification processes and schemes are one of the key results of this trend. However, according to many experts the concept of old-growth forests and its various definitions (*woodland that has existed since at least the 16th century at the same site* - Butler *et al.* 2002 - or defined *as not having had any human interference for over 100 years* - European Commission 2003a) remains a key factor. Lists of indicative species for ancient forests have been established for several countries (Hermy *et al.* 1999, FUSAGx/GF 2006). For Scandinavia, a system of "signal species" for the identification of forest habitats (incl. beech forest) with high conservation values has been introduced by the Swedish Forestry Agency (Skogsstyrelsen 2005).

In Sweden, as in several European areas, cutting of broad-leaved deciduous forests (including beech) for replacement by coniferous plantations (mostly spruce) was officially encouraged during the mid-20th century and until 1984, with the introduction of legislation that only allowed commercial forestry without changes in tree species on land with broad-leaved deciduous forest.

Threats

Luzulo-Fagetum beech forest is a widespread habitat with a large surface area in Continental Europe and the Carpathian area. Even if it does not seem to be threatened, some conservation evaluation studies in France or in Germany consider its conservation status to be unfavourable/inadequate, mainly because the structure and/or typical species are not in good condition. The following main threats have been identified:

Spruce and other non-native tree plantations

Spruce, especially in lowlands, or other coniferous plantations represent the main pressure on *Luzulo-Fagetum* beech forest. Vulnerability to strong acidophilus variations caused by repeated spruce plantations must be stressed: beech regeneration requires a moderate acid substrate (Bensettiti *et al.* 2001). Furthermore, stand composition is dominated by commercial tree species, exogenous species (*Pseudotsuga menziesii, etc.*) or beech itself, leading to monospecific stands (FUSAGx/GF 2006). In Scandinavia, the spontaneous spread of spruce from neighbouring commercial forest stands and plantations is a problem that has to be tackled locally and on a recurring basis (Naturvårdsverket 2005). The same situation occurs elsewhere in Europe, but, in general, spruce regeneration cannot invade intact beech forest because the shade tolerance of spruce is much less than that of beech. This problem is more likely to arise with selective browsing of young beech trees together with progressive canopy opening due to cutting or natural disturbances (Wilhelm pers. comm.).

Lack of horizontal heterogeneity

On beech forest massif scale, a high density of stands is expected in order to encourage wood production, leaving little space for clear stands, heliophilous (sun-loving) species and open ecosystems (FUSAGx/GF 2006). Large clear cutting for regeneration, providing areas for "open-biodiversity" are not the right answer as they penalize species with low dispersal capability (Gosselin & Laroussinie 2004). Vertical heterogeneity seems more complex and depends on taxonomic units (Gosselin & Laroussinie 2004).

Lack of decaying wood

Due to tree harvesting, beech forest never achieves decay status. Furthermore, dead or decaying wood is frequently cut for reasons of sanitation and tidiness. This leads to a deficit of microhabitats containing mega-trees and dead wood in comparison with the ideal situation of a « natural » forest to the detriment of associated fauna, fungi and flora (FUSAGx/GF 2006).

Deer density

According to Côté *et al.* (2004), deer have expanded their range and increased dramatically in numbers worldwide in recent decades. Besides economic damage to forest regeneration through selective foraging, deer affect the growth and survival of many grass, shrub, and tree species, modifying patterns of relative abundance and vegetation dynamics with cascading effects on other species (Flowerdew & Ellwood 2001, Fuller 2001, Perrins & Overall 2001).

The economic damage level is not the same for all the deer (Ballu 2006). It is high for *Cervus elaphus* (red deer) and *Dama dama* (fallow deer), noteworthy for *Rupicapra rupicapra* (chamois) and moderate for *Capreolus capreolus* (roe deer). This scale does not apply to biodiversity, and more research is needed in that regard. Important game pressure causes a deficit in natural regeneration of secondary tree species of *Luzulo-Fagetum* beech forest and sometimes of beech itself (FUSAGx/GF 2006). Furthermore, protection against deer has its own impact on biodiversity e.g. erection of deer fences kills many *Tetrao urogallus* (capercaillie) every year.

Soil compaction

Current exploitation techniques involve heavy machinery, which may cause noticeable changes in soil quality (Lamandé *et al.* 2005). Beech forest is prone to problems of soil compaction, particularly on silty soils (FUSAGx/GF, 2006). Soil porosity reduction tends to increase water retention and reduce soil aeration. Soil packing down has harmful consequences on tree growth because root systems do not develop well. Moreover, the reduction in soil macrofauna activity, following structural modifications, is detrimental to regeneration and tree development as it slows down soil mineralization, fragmentation and aggregation (Lamandé *et al.* 2005).

Pollution

Deterioration and a lower resistance to pathogens can result from atmospheric pollution: H_2SO_4, HNO_3, NOx, fluor and a high level of tropospheric ozone (Ballu 2006).

Climate change effects

Climate change effects on beech forest are numerous and considerable: a longer growing season, increase in forest productivity, a northward shift of species' ranges and alterations to the interactions between trees and pathogens are expected in the next decades (Legay & Mortier 2006). Modification of rainfall regimes could be a key parameter. Furthermore, climate change could lead to forest vegetation degradation due to extreme events like heavy rainfall, drought and storms (Ellmauer 2005).

A recent study involving simulation by two French research institutes (Badeau *et al.* 2004) reveals the change in beech distribution area due to global warming: probability of occurrence of beech will decrease markedly and *Luzulo-Fagetum* beech forests will be degraded or disappear within the next hundred years in the Atlantic area or in lowlands. A decline in the suitability of ecological conditions is to be expected at the western and southern margins of the distribution area, as well as at sites with low water capacity (Manthey *et al*. 2007). This habitat could be restricted to mountainous regions (http://www.nancy.inra.fr/extranet/com/carbofor/hetre.htm) and Continental ones, its presence will probability sink dramatically. The same trend is observed for fir and spruce. Above all, lowland beech forests are threatened by climate change.

For northern Europe, milder and more humid climate conditions are expected to lead to increased forest growth (IPCC 2007). For the beech forests in southern Scandinavia, this might include spread northwards and a change in habitat physiognomy.

2. Conservation management

General recommendations

It is the responsibility of the Member States to establish specific conservation measures and possible restrictions on the use of Natura 2000 sites, and local conditions will be the decisive factor for the management of each individual site (European Commission 2003a). Economic use of forests is not seen as an issue unless the practices lead to a deterioration of the conservation status of habitats or species. The Ministerial Conferences on the Protection of Forests in Europe (MCPFE) have adopted resolutions (Helsinki 1993, Lisbon 1998, Vienna 2004) which could provide the basis for forest management guidelines for Natura 2000 sites (European Commission 2003a). The main points concern forest management planning, natural regeneration, native species, diversification of both horizontal and vertical structures, encouraging the diversity of species, i.e. mixed stands, precautions for infrastructures, specific biodiversity measures such as maintenance of dead wood.

The Directorate-General for the Environment has addressed some guidelines and directions for forest management for Natura 2000 sites to Member State authorities (European Commission 2003a):

- "It is preferable to designate perimeters with a sufficient extension to allow conservation objectives to be integrated into existing management plans rather than to designate small plots corresponding exactly to the descriptions in the habitats reference guide.
- Conservation of habitats and species at the level of an entire site should be the result of measures in favour of habitats and species for which the site was designated, leading to a stable 'biodiversity offer' for the site as a whole. It is self-evident that, in the case of cyclical interventions (in space and in time), such a situation is more easily attained on sites covering larger surfaces.
- Interventions leading to temporary disturbance of forest cover on a limited space (for example, group cuttings) or with a limited intensity (such as thinning) are legitimate, provided that they allow recovery of the initial situation by natural regeneration, even if several stages of natural succession have to follow one another."

Active management

Some choices, which are decided within the forest management plan, will influence fieldwork (tree marking, monitoring), income or needs of security information. These interventionist decisions will be considered, by extension, as active management as well as classical forestry practices e.g. thinning. Furthermore, all of them clearly become active management when recovery or rehabilitation of favourable conservation status are at stake.

After a comprehensive worldwide bibliographic study (Gosselin & Laroussinie 2004), a French research centre made recommendations for biodiversity to the national public forest body (Gosselin *et al.* 2006). The axes that were determined constitute the basis for these guidelines; however, networks of protected forest areas and natural forests have been excluded. It is important to note that the guidelines focus on "active recurring management", a concept that has to be interpreted for *Luzulo-Fagetum* beech forests. Sometimes the naturalness of the forest is highlighted and some protected forest areas are dedicated to this, e.g. non-intervention is the primary concept for the management of *Luzulo-Fagetum* beech forests with high conservation values in southern Sweden (Naturvårdsverket 2005). This form of passive management will not be considered within this work.

Referring to Annex I of the Habitats Directive, the habitats of species within the forests should be a focus. In general, forest-dependant species can be classified according to their requirements for different management features (Golob 2004):

- Maintaining favourable conservation status of the forest habitat type in general with a close-to-nature forestry (most of the species, e.g. *Rosalia alpina*)
- Closer to primeval forests (e.g. *Dendrocopos leucotos, Ficedula parva*)
- Closer to succession stages (e.g. *Bonasa bonasia*, butterflies, etc.)

- Special guidelines for preservation of wetlands (or water courses) in the forest
- Species that require dead or weakened trees as special key habitats
- Other special requirements (e.g. *Barbastella barbastella, Myotis bechsteinii, Ursus arctos* require vast forest areas, butterflies require special plants and forest edges).

As described by Gosselin & Laroussinie (2004), it is crucial to encourage biodiversity at massif scale (or landscape scale) rather than maximize biodiversity at parcel scale. This is valid for both habitat structures and functions and for species conservation.

Species diversity and genetic variability

Management advice concerning tree species was summarised by Branquart (2005): encouraging indigenous species (with higher biodiversity potential), local ecotypes (adaptation to local conditions and sufficient genetic diversity), rare tree species and mixed species stands.

According to Gosselin & Laroussinie (2004), it is not clear if the dominant tree species will influence biodiversity, but native species will host higher biodiversity than exotic ones and deciduous rather than coniferous. It was demonstrated that different deciduous tree species have their own composition of saproxylic beetles and therefore non-dominant tree species (birch, maple tree, ash…) will increase biodiversity.

Mixed species stands seem not only to be better for biodiversity but for other key environmental parameters, too (resistance to stress and pests, soil protection, etc. (Branquart 2005)). However, homogeneous stands have their own interest and are not incompatible with Natura 2000 objectives (Gosselin & Laroussinie 2004).

Natural regeneration or the use of local seeds/seedlings is highly recommended, but in terms of active management, the extra costs linked to the implementation of local nurseries or seed collection seem not so frequent for beech forests. In general, natural regeneration will not generate extra costs (protection against ungulates are also needed with other regeneration methods - see below). When thinning stands, rare tree species have to be maintained and these thinning works have to be realized only when necessary for the target species. An alternative to "thinning" (as a typical treatment of stand level silviculture) is "crown release" limited only to target trees, including rare species and trees of other special ecological, aesthetic or artistic interest. An example for such a tree level silviculture is "Qualification-Dimensioning (QD)" (Wilhelm *et al.*1999, Bastien & Wihelm 2000, Wilhelm 2003).

Major principles concerning species diversity and genetic variability will be proposed during the management plan phase, but the management could be more active when deciding to eliminate invasive species (e.g. exotic or spruce) or to encourage some local rare species by thinning because of this objective. In Scandinavia, regular control and removal of invasive spruce from surrounding commercial forest and plantations is needed in order to maintain the nature values of beech forest (Naturvårdsverket 2005). Large-scale thinning within areas forested with coniferous species is proposed by Rameau *et al.* (2000) to restore beech forest. In France, there is a scheme to eliminate undesirable species (alien or autochthonous) from 8 habitats of the Directive which could be threatened by this, but it does not include *Luzulo-Fagetum* beech forest.

Cutting and regeneration, silvicultural system, management of young stands

In a multipurpose forest, it is wise to maintain a balance of age classes at massif scale as it will multiply habitats and edges and their perpetuation. Maximum heterogeneity (vertical and horizontal), as well as a good connectivity, for species with a low dispersal capability, will constitute an optimum. At a landscape scale, another optimum could be to get several regimes (reserves, coppices, even-aged stands, uneven-aged stands, etc.) in a mosaic. Both optima are difficult to attain. However, all silvicultural systems are of interest to biodiversity, and no specific cutting practices need to be banned because of biodiversity conservation (Gosselin & Laroussinie 2004). Only in specific conditions are irregular uneven aged stands necessary to protect soil (slope >30%, ONF 2005).

Best practice will depend on the objectives of the management plan. The key issues will be to maintain typical forest species and especially those of pioneer and terminal phases or species with low dispersal capability. Blanquart (2005) considers that, when the objective is to encourage biodiversity in beech forests, the regime should be irregular mixed stands (unevenly aged and at least 10 % of other deciduous tree species) with natural regeneration and some small regeneration areas (0.5 to 1 ha). The influence of the regime chosen on income is very difficult to estimate (time scale, numerous parameters, etc.) and the choice of silvicultural system is an active management decision with no clear costs. However, when changing this regime on a large scale, there is a cost linked to the disturbance to the economic scheme (change in harvesting time and quantities). In France, there is a financial scheme for Natura 2000 forest areas that makes it possible to alter the silvicultural regime by "irregularizing" the stands with a non-productive objective for the benefit of a list of species (*Tetrao urogallus, Ursus arctos, etc.*).

To maintain heterogeneity, Hunter (1990, *in* Gosselin & Laroussinie 2004), suggests having as many cutting and small regeneration areas (<0.15 ha) as large cutting areas. Another positive effect of small size cutting areas could be to encourage growth of a flora composed of forest species versus non-forest ones, even in the case of a larger cut after a certain time. Bus de Warnaffe 2002 (*in* Gosselin & Laroussinie 2004) suggests cutting less than 0.5 ha and considers that cutting more than 2 ha will damage the forest status of biological communities (flora, birds and carabids) and affect habitat continuity. Furthermore, thinning in earlier stages will encourage forest herbaceous and understory communities. Understory management offers several opportunities to create/maintain horizontal and vertical heterogeneity (Gosselin *et al.* 2006).

At local level, it is possible to favour the maintenance of coppices because some species depend of this regime: hazel grouse (*Bonasia bonasia*) in dense forests, flora and insects in open stages (Branquart 2005). This regime will favour the occurrence of cavities and is sometimes well adapted to poor soil. However, beech could be eliminated with this regime, possibly leading to a "substitute forest". Furthermore, the number of favourable cavities may be low after decades, and locally it might be wise to create some artificially.

Development of microhabitats, mega-trees and old trees, decaying or dead wood

According to Brustel (2001), there are between 60 and 90 m^3 of deadwood in boreal old natural forests and only 1.2 to 12 m^3 in exploited ones. According to several authors cited by Gosselin & Laroussinie (2004), the quantity of dead wood in natural forest of Eastern Europe can reach from 50 to 400 m^3 per hectare when it is a few cubic meters in managed forests. According to WWF (2004), deadwood volume reaches an average of 136 m^3/ha in old-growth beech forests. In France, the volume of deadwood from trees that have died within the last 5 years continues to increase to the current level of 1.7 m^3/ha, as compared to 1.2 m^3/ha 15 years ago (MAP 2006). Unfortunately, figures cannot be reliably compared with those of other European countries because calculation methods frequently differ (roots, dead wood on living trees, etc.). WWF is calling for an increase in deadwood in temperate forests to 20-30 m^3 per hectare by 2030.

In fact, the quality of deadwood is as important as quantity. Some deadwood classifications exist to describe the evolution, ranging from 3 to 14 categories depending on the authors (Brustel 2001). The duration of each step depends on the species ranging from a few years to several decades. Any kind of rot (brown, soft, white) has its own specific fungicenosis and zoocenosis (communities of fungi and animals), which can differ with species. Deadwood is not a single habitat, but instead a complex range of different microhabitats, which can change and evolve over time (WWF 2004). All the species of trees, categories of wood (from leaves to roots), sizes and positions have their own specific biodiversity. It seems that sunny deadwood has a higher value for saproxylic beetles (e.g. *Cerambyx cerdo*), but in this case, too, each habitat has its specific biodiversity and the saproxylic beetles hosted by beech trees prefer shade as does the species itself (Gardenfors *et al.* 1992 *in* Gosselin & Laroussinie 2004).

At least three items have to be considered regarding the maintenance or development of forest microhabitats: large old trees (or mega-trees, veteran trees), dead or decaying wood and ageing clumps. The spatio-temporal distribution of microhabitats as well as historical continuities will be key factors for biodiversity. Deadwood distribution and connectivity seem to influence saproxylic communities.

It is considered that old trees or large trees (for FNE 2006: very large tree: Ø 70 cm, large trees Ø 50 cm) are more important for saproxylic complexes because their habitats evolve slowly and in various ways with a durable creation of all the rarest habitats of modern forests (Brustel 2001). Bats also use fissures as refuge areas in relatively young trees (origin: frost cracks or storms) or cavities in older ones (origin: decay or woodpeckers). However, they mainly use living trees because of thermic regulation. This is another example of microhabitats not linked to dead trees. Lastly, cavities, and especially those with compost where *Osmoderma eremita* or *Limonescus violaceus* are found, are mainly developed in old bulky trees.

However, it is difficult to provide clear figures for managers and, as shown in the table below, a wide range of possibilities exist. Working groups or scientific institutions have proposed the following criteria in the framework of the conservation status assessment or of schemes to encourage biodiversity. The exercise was done for Wallonia (FUSAGx/GF 2006), Slovakia (Polák & Saxa 2005), Luxembourg (TR-Engineering 2004b), France (ONF 2005) and Germany (BFN 2003), where the Länder have applied the mythology with specific definitions or thresholds (two examples studied: Nordrhein Westfalen - Verbücheln *et al.* 2004 - and Brandenburg – MLUV 2004). See Table below.

Table 1. Amount of decaying wood, deadwood and mega trees proposed for the conservation status assessment of forests in several countries

Country/ region	**Definition**	**Favourable**	**Unfavourable - inadequate**	**Unfavourable – bad**
Decaying wood (stands)				
Wallonia		>2 individuals / ha	1 to 2 individuals / ha	< 1 individual / ha
Luxembourg	Standing and lying on soil, L> 2 m, Ø >60 cm for oak, beech and coniferous, Ø >40 for other trees	>3 individuals / ha	1 to 3 individuals / ha	< 1 individual / ha
France	Ø >35 cm	> 1 (in combination with others measures)		
Germany	Standing and lying on soil, L> 3 m, Ø >50 cm or large broken branches with Ø > 30 cm	>3 individuals / ha standing and lying	1 to 3 individuals / ha standing or lying	Up to 1 individual / ha standing or lying
Nordrhein Westfalen	Standing and lying, L> 2 m, Ø >50 cm	>3 individuals / ha	1 to 3 individuals / ha	Up to 1 individual / ha
Slovakia	L> 3 m, Ø >40 cm, equally distributed with different categories of decaying wood	>= 4 individuals / ha (very good) 2-3 (good)	1 individual/ ha	Less than 1 individual / ha
Total deadwood (volume)				
Wallonia	Standing and lying on soil	>20 m^3 / ha	7 to 20 m^3 / ha	Less than 7 m^3 / ha
Brandenburg	Ø >35 cm	>40 m^3 / ha standing and lying	21 to 40 m^3 / ha standing or lying	Less than 20 m^3 / ha
Mega-trees, old trees				
Wallonnia	Ø > 80 cm for hard wood and Ø > 50 cm for softwood	>3 individuals / ha	2 to 3 individuals / ha	< 2 individual / ha
Luxembourg	Ø > 60 cm for beech and oak and > 40 cm for other species	>5 individuals / ha	1 to 5 individuals / ha	< 1 individual / ha
France	Ø >35 cm	1 to 5 individuals / ha (in combination with others measures)		
Germany	Trees with cavities or nests OR Ø > 40 if cavities, dead parts, degraded bark OR Ø > 80 cm for beech and oak and noble?? deciduous, > 40 cm for other species	>= 6 individuals / ha	>= 3 individuals / ha	< 3 individuals / ha
Nordrhein Westfalen	Ø >= 80 cm in lowlands, Ø >= 70 cm in uplands and Ø >= 60 cm in high mountain	>= 6 individuals / ha	1 to 5 individuals / ha	< 1 individual / ha
Slovakia	Ø >= 60, equally distributed	>= 5 individuals / ha (very good) or 1-4 (good)	3-9 individuals / 10 ha	< 3 individuals / 10 ha
Brandenburg		>= 7 indiv./ ha	5 to 7 indiv./ ha	< 5 individuals / ha
Ageing and decaying clumps				
	Definition	**Favourable**		
France	Ageing clump (small stand exceeding the optimal economical criteria for the exploitation and going up to the double economical optimum age)	3% of the forest in general and 5 % in Natura 2000 areas		
	Decaying clump (small stand going up to the last death stage with no intervention)	1% of the forest in general and 3 % in Natura 2000 areas		

In temperate forest, Gosselin & Laroussinie (2004) consider that a minimum of 5-15 m^3 of deadwood per hectare is necessary to ensure a good level of saproxylic insect diversity, but this threshold is not sufficient for all species and we need locally higher volume.

The quotas of deadwood per hectare have to be considered as minimal, not optimal, and their distribution over the surface should be irregular as in natural forests (Brustel 2001). The spatio-temporal distribution of microhabitats as well as historical continuities are easier to manage in large forest massifs and will be key factors for biodiversity. A proportion of middle-aged trees, to ensure the future veteran trees, are needed (WWF 2004) and the management plans should take this into consideration.

According to Warms-Petit & Petit (2000), numerous shelters per hectares are needed for bats and a colony of 15 females of *Myotis bechsteinii* used more than 50 shelters on a few tens of hectares. The authors have suggested maintaining 25-30 shelters per hectare in old stands on 7-10 marked and selected standing trees. Artificial resting boxes can compensate the lack of natural shelters in exceptional circumstances.

Ranius (2000 *in* Gosselin & Laroussinie 2004), suggests maintaining ageing clumps to conserve *Osmoderma eremita* in the forest matrix, which divides the old parcels. Keeping old stands near the regeneration areas will reduce the impact on species with low dispersal capabilities. Another parameter to maintain these species is to lengthen the rotation between two cuts. In modern forestry, rotations last ± 150-160 years for oaks versus approximately 300 years in natural forests (FNE 2006). The duration of the rotation is 100-150 years for high beech forest (EEA 2006, ONF 2005) and longevity in beech can reach 300-400 years (Scherzinger 1996). In the framework of MCPFE criteria for biodiversity, MAP (2006) has estimated for several species an age limit greatly exceeding the admissible age for rotation. This estimate could be considered as a likely age of onset of physiological over-maturity or senescence phenomena under average conditions.

The following figures were proposed: beech 180 years, common oak 180 years, sessile oak 240 years, lowland fir 160 years, lowland spruce 160 years and mountain fir and spruce 200 years. The difference between the current rotation and this age limit could be used in management plans to develop ageing clumps that could be exploited at the limit age or maintained up to death (decaying clumps). In France it has been suggested that optimum age/diameter of exploitation in ageing clumps (ONF 2005) be doubled. These small stands will exceed the optimal economic criteria for the exploitation and going up to the double time/diameter. To implement these ageing clumps, it is advisable (ONF 2005) to make clumps of 0.5-5 ha heterogeneously dispersed on the massif and all designated at the same time. On the other hand, decaying clumps will constitute small stands of 0.5-3 ha up to the last death stage of the wood, with no intervention except for reasons of safety. Implementing them in poor quality or less productive areas has been suggested.

One of the main issues for deadwood conservation is education for both foresters and walkers. Moreover, risks for walkers and legal responsibilities have to be taken into consideration. In Frankenthal, a much-visited French nature reserve, there is a strict forest reserve in which technical inspections are carried out to decide whether or not to cut some of the old veteran or dead trees.

In some places where microhabitats have disappeared and where dependent species face extinction, artificial restoration methods have been tested, as in Italy (Cavalli & Mason 2003). The alien species *Quercus rubra* was eliminated through the restoration of dead wood using several techniques such as artificial windfall by uprooting, and bark and cambium girdling. Elsewhere, several artificial methods were used (Gosselin & Laroussinie 2004), e.g. nest boxes or cavities, rot inoculation, cutting or dynamiting the upper part of the trees.

Edges, glades and open areas within forests, forest wetlands

Management of edges to maintain a progressive structure (risen in tiers) will protect the forest against wind, increase landscape amenities, and create feeding areas for ungulates and habitats for species (birds, bats) that help to reduce pests (Branquart 2005). It will encourage heliophilous flora species and anthophilous species such as butterflies or *syrphidae*. The glades will have the same interest and increase the number of borders. Maintenance of open areas will encourage biodiversity.

First and foremost, it is not necessary to refill natural open areas, especially when they are not really suitable for reforestation. According to Gosselin & Laroussinie (2004), some permanent glades could be created by enlarging the corner in the intersections of tracks and pathways or by managing the edges along these access paths. Branquart (2005) suggests maintaining 10 metres unplanted on both sides of the pathways. Management should not include the use of pesticides and mowing should be done once in late summer or autumn or only every 2-3 years. In France, there is a scheme to create or rehabilitate glades in order to encourage forest species listed in the Birds and Habitats directives. The maximum area for a glade is considered to be 1500 m^2, above which the habitat is no longer considered forest habitat. A list of commitments, eligible actions and control items is proposed. The same exists for ponds, which are limited to 1000 m^2 to be eligible within forest schemes.

There are several kinds of wetlands in forests, e.g. humid forests, bogs and marshes, ponds, brooks and rivers, etc. This may create a need for specific measures for water control or to combat natural succession in bogs by cutting the trees.

Exploitation, forestry works and miscellaneous measures

Several relevant measures are clearly not active management; they are passive or even mandatory good practices (see below). However, some others may need specific investments:

- To cross the brooks and small streams and to avoid alterations to riverbanks or spawning areas, the use of temporary protections such as logs or pipes (Branquart 2005) are proposed.
- After assessment of their impact on biodiversity, rather than being asphalted, the proposed exploitation roads and tracks should be surfaced with local stone (Branquart 2005). After exploitation, some fences or barriers may be erected. Embankment may be interesting as it is impossible to re-open without heavy equipment.

In France, a scheme for Natura 2000 forest areas permits grants for one-off investments for forest road and tracks when species protection is involved: lengthening to divert existing roads, using obstacles or barriers to restrict the use of roads and tracks, anti-erosion measures, temporary protection of rivers. A list of commitments, eligible species and actions and control items is proposed. There is also a scheme to protect areas from manmade pressure by creating defenses or barriers. This could be useful to protect rare plants or nests (e.g. *Ciconia nigra*). A list of commitments, eligible actions and control items is proposed.

It is needed to inform the general public, to educate and for safety reasons, or to publicize bans or management measures implemented. Some boards may be needed for this.

Ungulate management

Many authors suggest maintaining a forest/game balance (FUSAGx/GF 2006). Natural regeneration appears to be jeopardized in many forests in Wallonia where deer density has doubled over the last 15 years (MRW 2007). Natural regeneration without protecting plants against ungulate damage is not always possible. At the same time, wire fences may damage species such as *Tetrao urogallus,* and it is better to restrict them to the most precious species or to replace them with wooden fencing or individual plant top covers. In Wallonia, total cost per metre for wire fences in 2005 was estimated at between €2.84 /m to €3.24 /m, and the cost of wooden fencing at €3.06 /m (Verté pers. comm.).

In Rhineland-Palatinate, wooden fencing has been shown to be insufficient to prevent roe deer browsing. Costs for fencing (wood or wire) including control, maintenance and removal are €10 /m for 1.6 m fence height and €15 /m for 2 m fence height. On the whole, fencing is not adapted to close-to-nature sylviculture as it limits regeneration in time and space. Prevention of deer browsing is now done by protecting individual trees (specific crêpe paper) and only in clumps.

Hunting schemes normally reduce ungulate density, but locally complementary culling has to be carried out by qualified foresters.

Beech forest restoration and recreation

Active management for biodiversity purposes within *Luzulo-Fagetum* beech forest is mainly dedicated to the restoration of habitat from a less favourable to a better conservation status. It has to be differentiated from beech forest creation, which could take tens or hundreds of years to be of conservation value. Unfortunately, proposals are occasionally put forward to compensate environmental impacts done on other very valuable habitats such as heath or moorlands.

However, with time, some plantations will acquire natural features, as was specifically tested in Sweden. Recreation of broad-leaved deciduous forest (primarily oak and beech) on land converted to spruce plantations during the 20th century was tested full scale in a LIFE Nature project in Söderåsen National Park, Sweden, 2002-2006 (LIFE02NAT/S/8483, "Restoration of deciduous forest in Söderåsen National Park). Regarding beech, *Luzulo-Fagetum* forest was the main target habitat. Plantation, as well as various techniques for sowing beechnuts in combination with different methods of soil treatment, were tested. The initial evaluations indicate that these are feasible and potentially conservation-effective methods although detailed precautions have to be respected in order to optimize survival of saplings and seedlings (Brunet & Oleskog 2006, Fiskesjö 2006).

An efficient and commonly applied method in Rhineland-Palatinate to replace pure spruce with beech is to underplant pure spruce stands older than 50 years with beech saplings. 40 to 60 young beeches in clumps of 5 to 7 m in diameter every 12 to 18 m are largely sufficient for this purpose (Landesforsten Rheinland-Pfalz 2003).

Indicators

The use of indicators as a shortcut to assess ecological conditions is highly dependant on the precise objectives to be studied. Generally, it is proposed to study forest continuity (temporal dimension) or forest naturalness, which, unfortunately, is hard to assess.

According to Kirby & Goldberg (2002), ancient woodland indicators are species that are more common in ancient woods than in recent sites, the presence of such species may therefore be used as evidence for the wood being ancient. Several authors have suggested that the occurrence of certain plants and lichens could distinguish ancient woods (Rolstad *et al.* 2002), but this has to be related to spatial scale or dispersal ability, too. In fact, the authors consider that concepts such as continuity or fragmentation are interesting, but only when a specified ecological feature or condition is defined within an explicitly spatio-temporal context.

No plant species are perfect ancient woodland indicators and the degree of association of a species with ancient woodland may vary across places. As an example, it is considered that the lichen *Lobaria pulmonaria* is an indicator of forest continuity (Branquart 2005), but several specialists consider that not to be the case in all circumstances. In fact, it was demonstrated that it is a good indicator of forest continuity on aspen (*Populus tremula*) in Finland (Rolstad *et al.* 2002). It is not sufficient to consider that we can use it as an indicator in any guidelines document. In Belgium, this species is mainly distributed on *Acer pseudoplatanus* within acidophilous beech forests (Verté pers. comm.).

It is necessary to distinguish at least two different features: some species will depend on the structural component of the forest *per se* and other species are hampered by poor dispersal ability (Rolstad *et al.* 2002). The more restricted their dispersal ability, the better they indicate continuity. More research is needed on this subject especially with forests stand whose history is known to aid in the understanding the dispersal ecology of their threatened inhabitants.

It is more accurate to use a whole suite of indicator species such as composite index of ecological continuity or saproxylic quality index. Developed in several countries, they are unwieldy to implement on a large scale (Brustel 2001). Recent studies conducted by the National French Institute for Agronomic research (INRA) identified floristic associations typical of ancient forests. Also, a list of floristic species is used in Wallonia.

Some criteria and indicators of sustainable management were prepared within the framework of the Ministerial Conference on Forest Protection in Europe (Lisbon 1998, amended in Vienna 2003). Six sustainability criteria and 117 qualitative and quantitative indicators were adopted, including 9 indicators on forest biodiversity: tract composition of species, regeneration, degree of naturalness, introduced species, deadwood, genetic resources, landscape pattern, threatened forest species and protected forest (Solano Lopez 2006, MAP 2006).

Other relevant measures

Maintenance of *Luzulo-Fagetum* beech forest is mainly linked to passive measures or mandatory good practices, active management being chiefly linked to restoration. The three following examples will illustrate this:

- To limit disturbance to birds, Branquart (2005) suggests cutting the timber and thinning between 1 July and 30 March (unless there are no sensitive species) and cutting grass and making swathes between 1 August and 30 March. When cutting an area, there is now a large consensus regarding maintaining wood scraps on the soil; this passive management does not involve any cost.
- Protecting forest soil (FUSAGx/GF 2006) is another measure in sustainable forest management, which should be mandatory and not considered as a source of extra costs.
- It seems that fertilisation causes the reduction of some *mycorrhizae* and increases fructification of some fungi (Gosselin & Laroussinie 2004). Fortunately, fertilisation is still quite rare (less than 1% of the area in France, Gosselin *et al.* 2006) and it is difficult nowadays to link absence of fertilisation to a loss of income. However, this has to be monitored for the future (wood energy development).

There are other examples of precautions regarding water and wetland quality, the proper use of pesticides and stocking timber.

The main relevant measure, which is not directly active management, is the drafting of management plans. This is widespread in public European forests and more and more in the private sector. Such management plans frequently include a monitoring scheme (e.g. ungulate density). The Swedish Environmental Protection Agency (SEPA) recommends a monitoring programme that includes the following elements, basically linked to the reporting requirements prescribed under Article 11 of the Habitats Directive (Naturvårdsverket 2005):

- Age and species distribution of trees, including spruce; with a 6-12-year interval, depending on trends and local conservation status
- Proportion of dead and decaying wood
- Recruitment of beech trees
- Typical species among lichens and bryophytes; with a 6-18-year interval, depending on trends and local conservation status

The second main passive relevant measure is the forest protected area schemes. There are several European wide policies (MCPFE) and research programmes (Latham & Frank 2005).

Because forests have multipurpose objectives (multifunctional approach), other relevant measures will concern surveillance and regulation of other activities such as leisure activities or tourism. Stakeholder involvement will play a key role in forest conservation. Sometimes, because it is difficult to calculate the cost of the proposed measures, private foresters will prefer recognition schemes rather than monetary compensation. France's Natura 2000 Charter Scheme was initially proposed by private foresters.

Cost estimates and potential sources of EU financing

Specific cost features for the habitat

After a comprehensive study of local practices and management plans, Thauront & Gourmain (2003) proposed a set of measures for French forests Natura 2000 agreements. There were two financial categories:

- A lump sum to buy a service associated with a long-term obligation, such as maintenance of decaying wood;
- One-off investments (non interest-bearing) for some specific works favouring species targeted by the Birds and Habitat directives (e.g. ponds or glade restoration.).

The European Commission accepted the scheme with some conditions, as the obligation to avoid new income and to find a clear and coherent methodology for the lump sum. Maintaining cut timber on soil was considered a good way to avoid income and increase dead wood.

The service offered by the increase of decaying wood volume in France was calculated for mature trees maintained for at least 30 extra years. Immobilization of the asset has a cost based on the market value of the tree and the set-aside of the land. Taking into consideration an updating rate and a certain number of trees per hectare, a complex mathematical formula was established to calculate the income foregone. Some parameters will depend on location, but an average of €75 for an oak and €89 for a beech was calculated (Thauront & Gourmain 2003, French Ministry of environment unpublished).

Incentive aids are also foreseen in Wallonia for private foresters and measures to promote biodiversity are mandatory in state forests (Branquart, 2005). In Nordrhein-Westfalen, compensation for economic losses are foreseen in association with the maintenance of well-defined levels of decaying trees and deadwood (European Commission 2003b).

In order to conserve some species, cutting needs to cease for a few months (e.g. discovery of a brown bear reproduction area) or be delayed for a few years (to restore the capercaillie population). In this case, it is very difficult to find a suitable compensation scheme (Thauront & Gourmain 2003) as there is no clear loss, just a delay in income. Furthermore, there is a certain variability in the preferences of the foresters that is not easy to take into account in the calculation methodology (Denis & Villetard 2002).

At last, there are some debates on the real cost of some conservation measures and the limit between active management and good practices. The main need seems be incentive actions (e.g. through LIFE projects) and incentive financial measures. The latter ones are unfortunately impossible with EU concurrency policies where only two kinds of costs are eligible: income foregone and extra costs.

Potential sources of EU funds

The cost issue has to be seen in the light of Article 17 of the Charter of Fundamental Rights of the European Union, which sets the principle of compensation for income foregone and the rules concerning concurrency.

Management measures for Natura 2000 were defined in the annexes of communication from the Commission on Financing Natura 2000 (COM 2004-0431 and its working documents). Four categories were defined with several types of activities for each of them. The first two concern the establishment of the Natura 2000 network and management planning, administration and maintenance of network-related infrastructure. They will not be considered within these guidelines. The latter two are more appropriate to this exercise, which is focused on active management. Monitoring items and action focusing on facilities to encourage visitor access or the action relating to land purchase are not of concern here. This means that only conservation management measures, management schemes and agreements, provisions of services and infrastructure costs will be considered.

Concerning potential sources of EU financing, a Guidance Handbook (Torkler 2007) presents the EU funding options for Natura 2000 sites in the period 2007-2013 that are, in principle, available at the national and regional level. Furthermore, an IT-tool is available on the EC web site (http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm).

For the period 2007-2013, several EU funds are available (EARDF, EFF, ERDF, and Cohesion Fund), which are implemented in accordance with national/regional programmes based on EU and national strategic guidelines. Furthermore, several project funds, whether interconnected or not with Structural Funds, can be used, as Interreg, LIFE+, the 7th Research Framework Program (FP7) or Leader+. However, some types of actions are not allowed for certain financial schemes, e.g. within LIFE+ recurring management is not eligible. Each Member State has identified the issues that are of most concern locally, and has prioritized

EU funds in order to address these issues. The integrated use of these resources will allow financing various management actions for areas with habitats listed in the Habitats Directive and included in the Natura 2000 network.

Among the diversity of sources for EU funding, the following funds might primarily be of interest for the management models on *Luzulo-Fagetum* beech forests:

- The European Regional Development Fund (ERDF), the Cohesion Fund and Interreg. These funds might be relevant in single cases although activities related to Natura 2000 sites mostly need to be integrated in a broader development context. However, the Interreg approach is more flexible but needs a European objective and partnership. Different geographical levels were defined and all of them have their specific rules, eligibility criteria and objectives.

- The Financial Instrument for the Environment (LIFE+). The 'Nature' component of LIFE+ supports best practice and demonstration projects contributing to the implementation of the Birds and Habitats Directives, but only exceptionally outside Natura 2000 sites. The 'Biodiversity' component is for demonstration and innovation projects contributing to the objectives of the Commission Communication 'Halting the loss of biodiversity by 2010 – and beyond'. Both the 'Nature' and 'Biodiversity' components focus on specific non-recurring management actions (at least 25 % of the budget). Recurring management is not eligible under LIFE+.

- The European Fund for Rural Development (EARDF). This programme has potential to cover several management activities that might be relevant, although the measures have to be covered in the National Strategy Plans and in the related Rural Development Plans (RDPs) in order to be eligible on a national basis. Furthermore, Leader+ projects have to be studied on a national basis. In the EARDF (Council Regulation N° 1698/2005), some financial schemes are foreseen for forests and wooded areas owned by private owners or by their associations or by municipalities or their associations. It is Article 46 (Natura 2000 payments to compensate restrictions on the use of forests) and Article 47 (forest-environment payments for voluntary commitments going beyond the relevant mandatory requirements). Both of them cover additional costs and income foregone resulting from the commitment made. Up to now, the success rate of these measures within rural development seems quite low.

Furthermore, support for non-productive investments are foreseen under Article 49 for all kinds of forest when the investments are linked:

- to the achievement of commitments undertaken pursuant to the forest-environment payments (Article 47);
- to the fulfilment of commitments undertaken pursuant to other environmental objectives (including Natura 2000);
- to enhance the public amenity value of forest.

The second abovementioned item was used by France to co-finance the forest Natura 2000 agreements. Furthermore, all forests are eligible for this scheme. Thanks to the high resilience of forest habitats, irregular one-off non-productive investments can be used to improve the conservation status of the habitat.

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