Ann. For. Res. 56(1): 217-245, 2013

ANNALS OF FOREST RESEARCH
www.e-afr.org

Sustainable forest management of Natura 2000 sites: a case study from a private forest in the Romanian Southern Carpathians

H. Walentowski, E.D. Schulze, M. Teodosiu, O. Bouriaud, A. von Heßberg, H. Bußler, L. Baldauf, I. Schulze, J. Wäldchen, R. Böcker, S. Herzog, W. Schulze

Walentowski H., Schulze E.D., Teodosiu M., Bouriaud O., von Heßberg A., Bußler H., Baldauf L., Schulze I., Wäldchen J., Böcker R., Herzog S., Schulze W., 2013. Sustainable forest management of Natura 2000 sites: a case study from a private forest in the Romanian Southern Carpathians. Ann. For. Res. 56(1): 217-245, 2013.

Abstract. Biodiversity and forest management are analyzed for a 500 ha privately owned forest within the Natura 2000 area "ROSCI0122 Munții Făgăraş". Habitat types and indicator species are identified to measure environmental quality. Working towards an integrated approach to conservation, a range of options that will result in sustainable forest management are then considered. For beech forests light heterogeneity emerges as a crucial management target to ensure tree species richness and structural diversity as a basis for saving indicator species such as *Morimus funereus*, *Cucujus cinnaberinus, Bolitophagus reticulatus* and *Xestobium austriacum*. For spruce forests thinning over a broad range of diameters and maintenance of veteran trees would provide habitats for indicator species such as *Olisthaerus substriatus*. The populations of a number of bird species would be increased by strip-harvesting slopes: species such as *Tetrao urogallus, Bonasia bonasia* and *Ficedula parva* prefer forest margins. Steep slopes, and the areas around springs and watercourses, as well as rock faces, should remain unmanaged. Future management should start with a grid-based inventory to create an objective database of forest structure and life. An example is presented for high-elevation spruce forest. The inventory should quantify the variations in diameter, height and volume of trees per unit area. Such data would allow the advanced planning of forest operations. We discuss a wide range of administrative and organizational changes; changes that are needed for the sustainable forest management of the vast close-to-natural forests of the Munții Făgăraş, the maintenance of the *Nardus* grasslands and the protection of wetland vegetation around springs and streams in this Natura 2000-area.
Keywords Natura 2000, Integrated Forest Management, *Fagus*, *Picea*, Romania, Făgăraş, Boişoara.

Authors. H. Walentowski, H. Bußler - Bavarian State Institute of Forestry, Hans-Carl-v.-Carlowitz-Platz 1, 85354 Freising, Germany; E.D. Schulze, I. Schulze, J. Wäldchen - Max-Planck Institute for Biogeochemistry, PO Box 100164, 07701 Jena, Germany; M. Teodosiu, O. Bouriaud - Forest Research and Management In-

stitute, Calea Bucovinei 73b, 725100 Câmpulung Moldovenesc, România; A. von Heßberg - Theta 28, 95463 Bindlach; L. Baldauf - Görmer & Baldauf GmbH, Am Kirchberg 6a, Burkersdorf, 07570 Harth-Pöllnitz, Germany; R. Böcker - University of Hohenheim, Institute of Landscape and Plant Ecology, Germany; S. Herzog - Dr. Ion Ratiu 9, 550012 Sibiu/Hermannstadt, România; W. Schulze - University of Hohenheim, Dept. of Plant Systems Biology, 70593 Stuttgart, Germany.
Manuscript received November 02, 2012; revised November 09, 2012; accepted March 08, 2013; online first March 20, 2013.

Introduction

Forests provide a diverse mixture of environmental services. Beyond their historical role of wood supply, increasing attention is now paid to the maintenance of biodiversity and carbon reservoirs, protection of water resources, and recreation. The acknowledgement of these additional services requires a re-evaluation of forest management, which must now balance the costs of the ecological against the commercial functions of forest (Wippel et al. 2013).

Establishing rules for ecologically sustainable forest management is a challenge for forestry and nature conservation organizations across the European Union (MCPFE 2003). Moreover, there are regional differences in the urgency and ecological significance of such rules. The 2007 enlargement of the European Union to include Bulgaria and Romania has required some amendments to be made to the EU nature conservation legislation – the “Birds Directive” (2009/147/EC) and the “Habitats Directive” (92/43/EEC). In Bulgaria and in Romania, a major natural heritage (BirdLife European Forest Task Force 2009) is confronted by large wood resources, relatively low property prices and pressure to exploit the commercial resources of the forest. This creates an urgent need to develop best-practice forest management, which addresses the European priority of combining commercial forest management with nature conservation. One route to achieving this goal would be for the international ecological community to establish innovative pilot projects and demonstrate how biodiversity in forest ecosystems can be maintained in parallel to commercial exploitation.

The study reported here has the objective of examining the diversity and structure of a managed forest area, and of establishing the contribution of forest management to the protection of soils and water resources, and the habitats of protected plants and animals. We demonstrate how a grid-based inventory approach could be widely used to research the forest composition and commercial potential. The results of this research could then be used to draw up best-practice forest management plans.

Characteristics of Boișoara forest

Site location and Natura 2000 area

The study-site is the Boişoara forest, that is owned and managed by the Boişoara Forest Enterprise. The forest is located in the Făgăraş Mountains, that are in the southern bow of the Carpathian Mountains, Boişoara forest (Figure 1) stretches across Mt Caligaru between the River Boia Mare in the west and the River Topolog in the east. The forest ranges between 790 and 1715 m a.s.l. (above sea level).

The Boişoara forest is part of the Natura 2000 area of the Romanian Site of Community Importance, “ROSCI0122: Munții Făgăraş“. The area of ROSCI Munții Făgăraş is 198,512 ha and ranges in altitude from 350 m to 2500 m a.s.l. at 24°44’E and 45°31’N (Figure 1). According to the biogeographic classification of Europe the Făgăraş Mountains belong

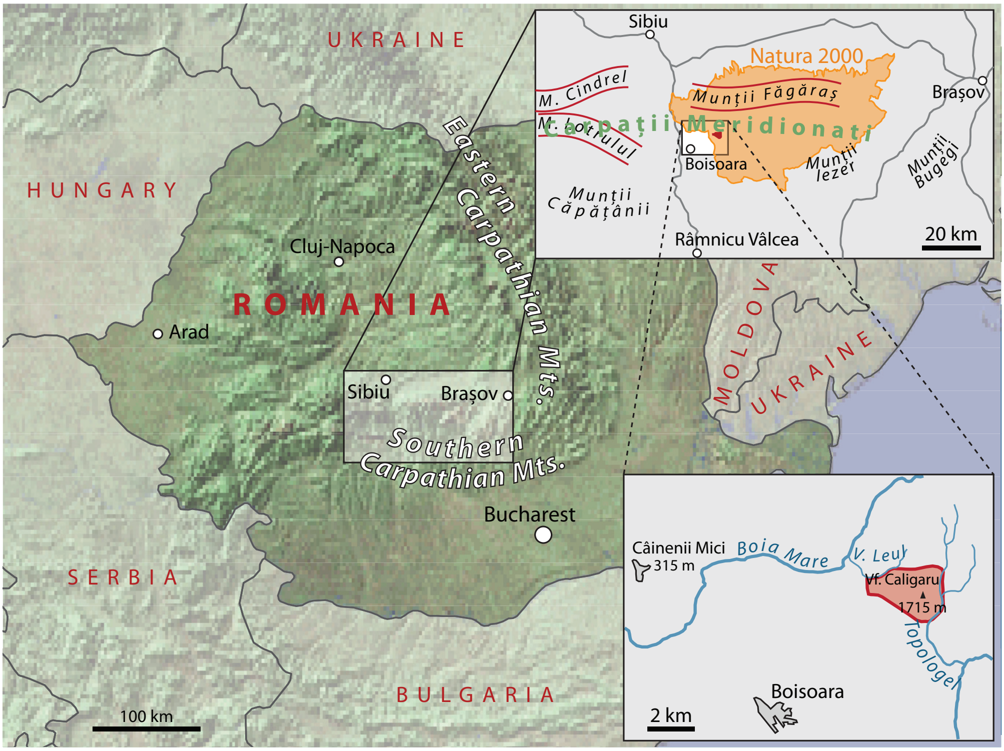


Figure 1 Geographic map of the study area: Southern Carpathian Mountains (up right) and Boişoara Forest (bottom right)

Table 1 Elevation zones of the southern Carpathian Mountains (Mayer 1984, Coldea 2004)

Level	Zone	Zonal vegetation	Annex I-habitat type Habitats Directive	Tree species	Elevation (m a.s.l.)	Temperature average (^{0}C)	Annual rainfall (mm)
pediment							
lower	colline	Euro-Siberian steppic woods with *Quercus spp.*	91I0^x	*Quercus, Acer, Tilia, Sorbus*	200-500	>9-10.5	< 650
median	colline to submontane	Dacian oak-hombeam forests	91YO	*Carpinus, Quercus, Tilia,*	500-700	8-9	650-800
upper	submontane	warmbeech forests	91VO	*Fagus, Carpinus*	700-900	7-8	
montane							
lower	lower montane	cool beech forests		*Fagus*	900-1100	6-7	
median	midmontane	mixed mountain forests	91V0, 9110	*Fagus,Abies,Picea*	1100-1300	5-6	800-1100
upper	upper montane	mixed mountain forests		*Picea,Abies,Fagus*	1300-1500	4-5	
subalpine							
lower	lower subalpine	spruce forests	9410	*Picea*	1500-1800	2.5-4	1100-1200
upper	upper subalpine	krummholz	4060, 4070	*Pinus mugo*	1800-2300	0-2.5	
crest							
peak	alpine	boreo-alpine mosaic vegetation (grasslands,screes, rocks,snow beds)	6150		2300-2500	-1 -0	1200-1400

to the "Alpine Region" (EEA 2012). These mountains are of biogeographic significance as pleistocene refugi and as a link between different biogeographic regions. The flora and fauna of the Boişoara forest are typical of this region. Carpathian endemic species, and the Carpathian-Balkan and Alpine-Carpathian elements are biogeographically significant and of importance to conservation. According to recent analyses of the flora (Stancu 2010, Vintilă 2012) the territory belongs to the Holarctic region, the Eurosiberian subregion, the Central-European domain, the Eastern-Carpathian Dacian province, the Southern Carpathian circumscription, and the Făgăraş Mountains district (Borza & Boşcaiu 1965).

The Făgăraş Mountains comprise a vast and coherent mountain landscape of forests and grasslands with intact wildlife corridors. There is a low population density and continuous forest covers about 75% of the land, the remaining area is grass and heathland, but this is not used for agriculture (Table 2, Appendix). Beech and spruce forests cover about 70% of the area. "Priority" habitats (in danger of disappearing at European level) may have less than 10% of total cover, but deserve particular attention (Table 3, Appendix). *Nardus* grasslands are particularly important, with more than 15% of this habitat type in Romania being located in ROSCI Munții Făgăraş.

ROSCI Munții Făgăraş contains a very rich fauna and flora (EEA 2006), see Table 2 which is focused on the Annex II-species of the Habitats Directive listed on the respective Natura 2000 standard data form. Plant species names follow the Romanian flora (Ciocârlan 2009). Animal species and plant community names follow Natura 2000 checklists (EEA 2006, Gafta & Mountford 2008).

Table 2 Species listed on Annex II of Council directive 92/43/EEC in the Natura 2000 area ROSCI0122 Munții Făgăraş

Mammals (6 species)	Amphibians and Reptiles (3 species)	Fishes (4 species)	Invertebrates (13 species)	Plants and Mosses (7 species)
*Canis lupus**	*Bombina variegata*	*Barbus meridionalis*	*Callimorpha quadripunctaria*	*Campanula serrata**
Lynx lynx	*Triturus cristatus*	*Cottus gobio*	*Carabus hampei*	*Drepanopladus vernicosus*
Lutra lutra	*Triturus montandoni*	*Eudontomyzon mariae*	*Chilostoma banaticum*	*Liparis loeselii*
Myotis myotis		*Gobio uranoscopus*	*Euphydryas aurinia*	*Eleocharis cornioloca*
Rhinolophus hipposideros			*Lucanus cervus*	*Tozzia carpathica*
*Ursus arctos**			*Lycaena dispar*	*Poa granitica* subsp. *Disparilis*
			Morimus funereus	*Meesia longiseta*
			Ophiogomphus cecilia	
			*Osmoderma eremita **	
			Pholidoptera transsylvanica	
			*Rosalia alpina **	
			Stephanopachys substriatus	
			Vertigo angustior	

Note. Source data: Natura 2000 standard data form. The priority species are indicated by an asterisk (*).

Environmental features

The area was lifted during the Alpine uplift in the Cretaceous period. The steep northern faces of the Southern Carpathians lack any foothills, while the southern slopes are elongated, flat ridges of 40 to 50 km length. The mountains are composed of crystalline gneisses and mica-schist. Specific soils at lower and mid elevation are Dystric Cambisols (brown and acid brown soils) and Lithic Leptosol (very shallow soils over rock). Higher elevations are covered by brown Podzols and Alpine humic-silicate soils. Headwaters contain alluvial sites, escarpments, and woody debris. Valleys contain gley on loamy or clayey alluvium.

At the median pediment (700 m a.s.l., Table 1) monthly average temperatures range between about -4° and -3° in January and 18° to 20° in July; annual precipitation is 700 to 800 mm, with dry summers. Following Mayer (1984) and Coldea (1991, 2004) the range of elevation zones results in a gradient of about 10°C in temperature and of about 700 mm in annual rainfall over a distance of about 50 km. Thus, the altitudinal change in climate is greater than would be encountered by a change of many degrees of latitude (Table 1).

Vegetation changes with altitude from deciduous beech to evergreen coniferous forest, resembling latitudinal vegetation zones. The highest point of Boişoara at Mt. Caligaru (1715 m a.s.l.) is about 100 m below the timberline in the Făgăraş Mountains. At the treeline, the mean annual temperature is estimated to be +2°C and the mean annual precipitation >1100 mm per year.

Forest history and human intervention

The history of the forest is not well documented because of changes in Romania's political and economic system. Probably the stand structure is the best indirect indicator of the past.

Boişoara Forest extends across the historic border between the Austro-Hungarian Monarchy (region of Transylvania or Siebenbürgen) and the kingdom of Romania (Vâlcea or Walachei), which runs north-south across the top of the mountain range. During World War I, the grassland of Caligaru was used as an Austrian military base. The present road along this border was built by the military during World War I. On the East side of Caligaru there are trenches (Figure 1A, Suppl. material). The steep slope running parallel with the border also appears to be a military artefact. No military action or battle was reported for this area during the World War I. During World War II this border had no military significance. No military relics (ammunition, metal) have been found.

It is very likely that the subalpine area had been deforested before World War I, because it would not make sense to dig trenches in a dense forest. The abundant occurrence of *Veratrum album* in dense stands of *Picea* may further indicate a former grassland cover (Figure 1B, Suppl. material).

In the montane elevation (middle part of the slope) charcoal was found within levelled circular structures, indicating charcoal works. Charcoal was produced until the Ceauşescu era (1956-1989). Forests near these charcoal works also have a high proportion of *Betula* and *Populus* indicating disturbance.

Following World War I, the inhabitants of Transylvania, mostly of German origin, were invited to vote for their integration either into Hungary or into Romania. The majority elected for Romania, even though many emigrated after World War I and II to Germany or Austria.

After World War II Romania was under Soviet occupation (1944 to 1956). Extended areas of forest were clear-cut in the Carpathian Mountains to serve as war-compensation. Topographic maps of the year 1976 produced by Russia during the period when Romania was under the occupation of Soviet Unition show large deforested areas, which were, according to information from local forest engineers, in part compensation cuts.

A Romanian government followed the Soviet period headed by G. Gheorghiu-Dej from October 1956 until 1965, who was followed by the dictator N. Ceauşescu until December 1989. Ceauşescu reserved large forest districts as personal hunting grounds. On the east side of Boişoara forest old hides for bear hunting and the ruins of a large villa are evidence that this old growth forest was part of a Ceauşescu hunting range (Figure 1C-D, Suppl. material). The present borders of the Romanian hunting districts still follow the partitioning introduced by Ceauşescu, and containhuge areas per sistrict (>10,000 ha) which are difficult to control operatively and administratively.

Boişoara forest belonged to the Popovich family, who have lived in Curtea de Arges, probably since the 17th century. The title of the property was previously under the name of the Mrs. Necula who inherited the property of Popovich, but upon her death in 2012 the son Necula inherited the property and received the title. The borders of the forest are documented in the city archive of Curtea de Argeş under the family name of Popovich with qualitative descriptions of the terrain following streams and mountain ranges.

Private property was expropriated during the communist period (1944 until 1989). The Romanian forest administration mapped the region in the 1960s and subdivided the forest into management units (parcele), and marked these with stones and border trees. Forest maps were not geo-referenced and remained separate from the geodetic map of Romania.

The Popovich's property rights were restored in 2000 on behalf of Mrs Necula, but only after harvests had taken place in the lowermost elevation of the western corner. About 10 transects, visible on aerial photographs, indicate wood extraction by cable-crane over lengths of about 200 m and 30 m width in the northern part.

Following restoration of the property, the owners were legally required to join the new forest administration. However, Necula Popovich did not pay the necessary dues and the forest administration therefore made unauthorized cuttings in 2002. The distribution of the proceeds contravened the management rules (one third for the owner, one third for the forester, and one third for the controlling agent). Only by 2006 was a management plan introduced that quantified wood stocks and prescribed wood harvests over a 10-year management period (i.e., until 2016). A skidding track was built in 2008 to give access to the subalpine belt of *Picea* for clear-cutting two areas of 1.2 ha each (30% for the owner, 70% for the forest agents). Boişoara forest was sold by Necula to Boişoara Forest Enterprise in 2011.

In summary, the upper mountain zone had been deforested before World War I and was probably used as alpine pasture, as indicated by heavily branched *Picea* trees which grew up as isolated trees, but which were later surrounded by *Picea* succession (see Figure 5). In the 1920s there was probably a state-controlled afforestation programme with large scale plantation of *Picea*. This would explain the abrupt border of the *Fagus* and the *Picea* zone in Boişoara forest and the lack of any well-developed mixed mountain forest with both *Picea, Abies* and *Fagus* in the upper montane zone (1300 - 1500 m a.s.l.) for most part of the region.

The *Fagus* zone was probably cut after World War I (upper range of the stream Leu). A few isolated *Fagus* trees remained and these can be recognized today as deeply branched large trees in the present stands. Wood was extracted by dragging along the courses of mountain streams. Stands remained uncut if there were no streams for extracting wood within reach. These old stands were partially cut during the Ceauşescu period. Additional harvests took place after restoration of private ownership.

The large scale and intensive forest use after both World Wars had no significant long lasting effect on the species composition of the forest floor vegetation, even though the number of species representing pristine forest are more abundant at other locations in the Carpathian Mountains. The present canopy is rich in early succession tree species. Old growth stands and late succession species, such as *Acer* and *Ulmus*, are rare. It remains unclear where the presently detected relict species of insects survived the periods of intense forest use. Was the number of remaining isolated trees sufficient? Was there a large volume of slash? Or were 100 years sufficient for regeneration of the biota? What was the role of neighbouring forests in re-migration (habitat connectivity)?

Biodiversity drivers and landscape patterns

The outstanding biodiversity of the south Romanian beech forest region within the mountain ranges of an alpine region results from palaeo-historic connections to the flora and fauna of the Neogene Period and Pleistocene refuges which were the basis for macroevolution (palaeo-endemic species, neo-endemic species). A short distance to Pleistocene refuges allowed an early expansion of spruce and of broadleaf tree species during inter- and postglacial periods. The high mountain region also promoted divergent microevolution of species. The habitat tradition, i.e. preservation of coherent forest areas with remains of primeval beech forests even in the Holocene, supported an integrity of succession and species pools (genetic and species diversity) in forest tree communities.

Boişoara forest benefited from this exceptional framework. The high mountain terrain provides enormous spatial contrasts with respect to local climatic conditions. Untamed mountain torrents and steep-sided valleys also may have prevented human colonization and subsequent human influence on vegetation dynamics. The patterns and ecological gradients discussed below are of crucial importance for the flora and fauna of Boişoara forest.

Biodiversity patterns in space (ecological zones)

Two spatial gradients are important for plant species distributions and forest communities elevation and the soil properties.

(i) Elevation. The upper pediment zone (Table 1) is dominated by deciduous forests, where beech is accompanied by lowland species of the Transylvanian mixed oak-hornbeam forest, such as *Carpinus betulus* and *Prunus avium.* In the lower montane zone *Fagus* is becoming increasingly dominant. Above 1100 m (mid-montane level) the pure deciduous forests change only locally to mixed conifer-deciduous forests (*Fagus sylvatica, Abies alba* and *Picea abies*). The upper montane and the lower subalpine zones are covered by coniferous forests, which belong to the Habitat Type 9410: "Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceetea*)". They are dominated by spruce (*Picea abies*) with admixed *Abies alba* extending to the uppermost elevation (1715 m Mt. Caligaru).

(ii) Soil acidity and nutrients. The species poverty of vascular plants in forests on acidic, nutrient-poor sites, compared to sites with high base saturation and nutrition is well-known. However, despite an acidic bedrock of mica the forest floor vegetation shows locally species with high demand for base saturation, such as *Corydalis solida*.

Coarse woody debris has important functions for the nutrient cycle of potassium, nitrogen and calcium and for late-season water storage. Deadwood as a driver for species diversity is considered to be particularly important on acid soils, as proved for snails by Müller et al. (2005b), and for saproxylic beetles by Lachat et al. (2012).

Biodiversity patterns in time (ecological succession)

Very important drivers of succession are based on three types of disturbances.

(i) Gap-driven ecosystems resulting from rare stand-initiating events. Most forest stands have a closed canopy with relatively low wood volumes. One may classify them as "optimal phase" of a natural succession. These are gap-driven ecosystems with regeneration taking place in small gaps created by the death of an individual tree.

(ii) Disturbance driven-ecosystems resulting from frequent stand-initiating events. Perfect examples are relatively unmodified alluvial sites belonging to Habitat Type 91E0* "Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicon albae)" and 6430 "Hydrophilous tall-herb fringe communities of plains and of montane to alpine levels". Regular flooding is an essential disturbance to maintain this structure.

(iii) Managed ecosystems resulting from singular or frequent stand-maintaining events. Earlier succession stages exist from clear cuts after World War I and II. Pioneer species still contribute to the canopy cover (*Populus, Betula*). Only on smaller areas may one find old-growth stages and regeneration. In addition, there are the anthropogenic grasslands resulting from deforestations centuries ago and belonging to Habitat Type 6230* "species-rich *Nardus* grasslands on siliceous substrates in mountain areas". These require continuation of the current management system to prevent forest re-establishing itself.

Main forest types

Phytosociological and site-ecological characterization

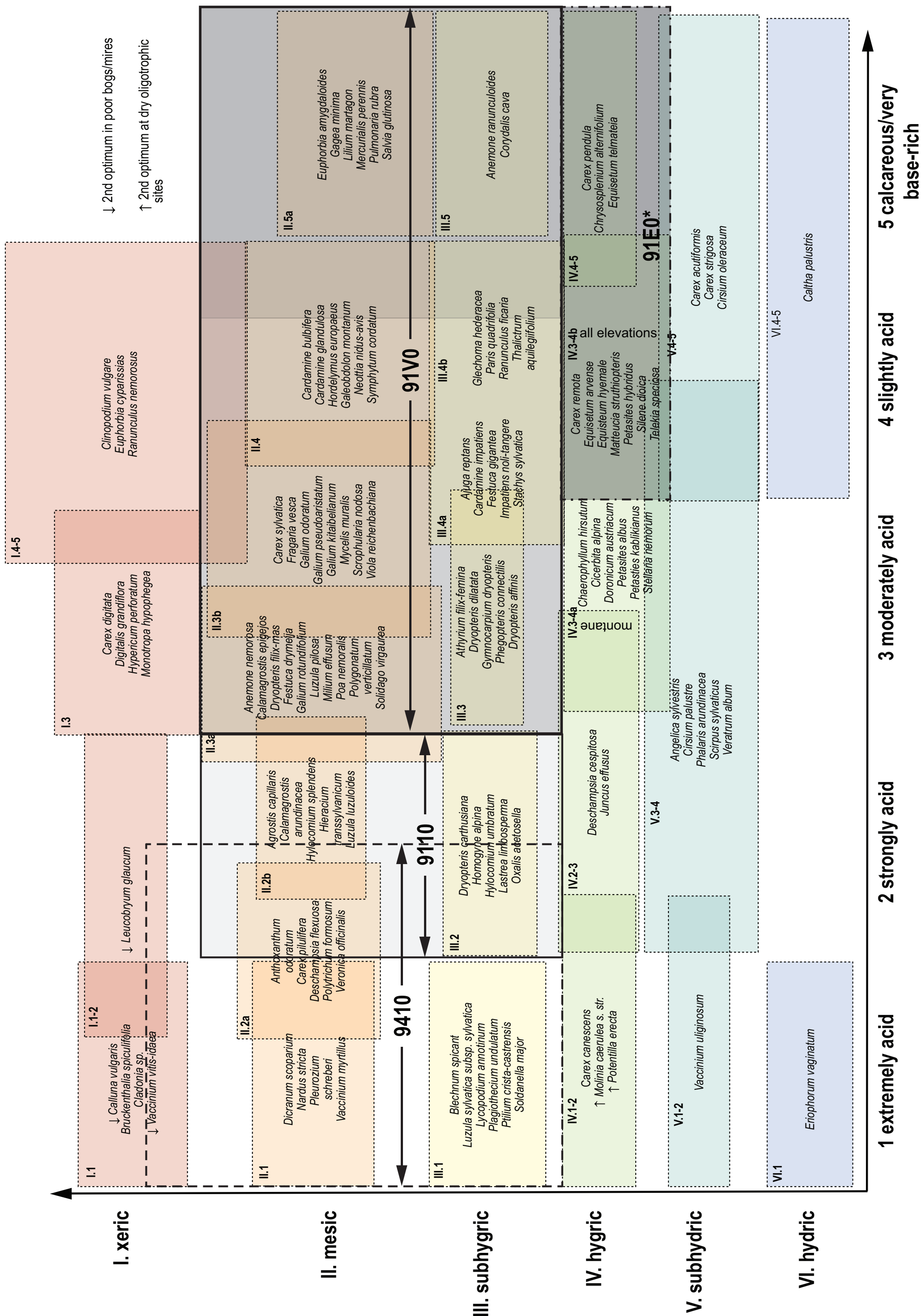
The main plant communities, as summarized in relation to soil acidity and water supply (Figure 2) extend across a very wide range of soil acidity, water status and elevation.

The main habitat type at lower elevation is the "Dacian beech forests of the Symphyto cordatae-Fagion (Habitat Type 91V0)". The defining beech forest communities of the type (Symphyto cordatae-Fagetum Vida 1959, Pulmonario rubrae-Fagetum (Soó 1964) Täuber 1987) are composed of Carpathian endemics (*Symphytum cordatum, Dentaria glandulosa*), Carpathian-Balkan species (*Pulmonaria rubra)*, pre-Alpine species (*Euonymus latifolia* and *Salvia glutinosa*), and even boreo-circumpolar distributed species (*Polystichum braunii*). Obviously, the beech forests are by no means a uniform "community" but contain species of vastly different origin and geographical distribution, which by chance meet in the present Dacian beech forest (Bohn & Bergmeier 2003, Moravec 1985).

Due to the species combination and the ecological indicator groups, the prevailing beech forest association of the Boişoara Forest is classified as the Dentario glandulosae-Fagetum on moderately acid, brown soil, rich in humus of the mull or moder type (Mayer 1984). The most common sites are moderate fresh cambisols on steep slopes. On soils with higher base saturation it is replaced by the Pulmonario rubrae-Fagetum. A nutrient-poor

Figure 2 Indicator species ecogram of diagnostic understorey plant species in forests. Based on Ewald (2007), modified for some Carpathian-Balkan species ⟶

Habitat type		Plant association
9410	Acidophilous spruce forests	(*Soldanenello majoris-Piceetum*)
9110	Luzulo-Fagetum beech forests	(*Hieracio rotundati-Fagetum*)
91V0	Dacian beech forests	(*Dentario glandulosae-Fagetum*)
91V0	Dacian beech forests	(*Pulmonario rubrae-Fagetum*)
91E0*	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*	(*Telekio speciosae-Alnetum incanae*)



↓ 2nd optimum in poor bogs/mires
↑ 2nd optimum at dry oligotrophic sites
I. xeric
II. mesic
III. subhygric
IV. hygric
V. subhydric
VI. hydric
1 extremely acid
2 strongly acid
3 moderately acid
4 slightly acid
5 calcareous/very base-rich
9410
9110
91V0
91E0*
I.1
↓ Calluna vulgaris
Bruckenthalia spiculifolia
Cladonia sp.
↓ Vaccinium vitis-idaea
I.1-2
↓ Leucobryum glaucum
I.3
Carex digitata
Digitalis grandiflora
Hypericum perforatum
Monotropa hypophegea
I.4-5
Clinopodium vulgare
Euphorbia cyparissias
Ranunculus nemorosus
II.1
Dicranum scoparium
Nardus stricta
Pleurozium schreberi
Vaccinium myrtillus
II.2a
Anthoxanthum odoratum
Carex pilulifera
Deschampsia flexuosa
Polytrichum formosum
Veronica officinalis
II.2b
Agrostis capillaris
Calamagrostis arundinacea
Hylocomium splendens
Hieracium transsylvanicum
Luzula luzuloides
II.3a
II.3b
Anemone nemorosa
Calamagrostis epigejos
Dryopteris filix-mas
Festuca drymeja
Galium rotundifolium
Luzula pilosa
Milium effusum
Poa nemoralis
Polygonatum verticillatum
Solidago virgaurea
II.4
Carex sylvatica
Fragaria vesca
Galium odoratum
Galium pseudoaristatum
Galium kitaibelianum
Mycelis muralis
Scrophularia nodosa
Viola reichenbachiana
Cardamine bulbifera
Cardamine glandulosa
Hordelymus europaeus
Galeobdolon montanum
Neottia nidus-avis
Symphytum cordatum
II.5a
Euphorbia amygdaloides
Gagea minima
Lilium martagon
Mercurialis perennis
Pulmonaria rubra
Salvia glutinosa
III.1
Blechnum spicant
Luzula sylvatica subsp. sylvatica
Lycopodium annotinum
Plagiothecium undulatum
Ptilium crista-castrensis
Soldanella major
III.2
Dryopteris carthusiana
Homogyne alpina
Hylocomium umbratum
Lastrea limbosperma
Oxalis acetosella
III.3
Athyrium filix-femina
Dryopteris dilatata
Gymnocarpium dryopteris
Phegopteris connectilis
Dryopteris affinis
III.4a
Ajuga reptans
Cardamine impatiens
Festuca gigantea
Impatiens noli-tangere
Stachys sylvatica
III.4b
Glechoma hederacea
Paris quadrifolia
Ranunculus ficaria
Thalictrum aquilegiifolium
III.5
Anemone ranunculoides
Corydalis cava
IV.1-2
Carex canescens
↑ Molinia caerulea s. str.
↑ Potentilla erecta
IV.2-3
Deschampsia cespitosa
Juncus effusus
IV.3-4a
montane
Chaerophyllum hirsutum
Cicerbita alpina
Doronicum austriacum
Petasites albus
Petasites kablikianus
Stellaria nemorum
IV.3-4b
all elevations
Carex remota
Equisetum arvense
Equisetum hyemale
Matteucia struthiopteris
Petasites hybridus
Silene dioica
Telekia speciosa
IV.4-5
Carex pendula
Chrysosplenium alternifolium
Equisetum telmateia
V.1-2
Vaccinium uliginosum
V.3-4
Angelica sylvestris
Cirsium palustre
Phalaris arundinacea
Scirpus sylvaticus
Veratrum album
V.4-5
Carex acutiformis
Carex strigosa
Cirsium oleraceum
VI.1
Eriophorum vaginatum
VI.4-5
Caltha palustris

sub-association of the Dentario glandulosae-Fagetum is the Dentario-Fagetum festucetosum drymejae occurring on steep slopes with brown acidic soil and loose rocks.

Less common are beech forests on acid soils with reduced biological activity and litter decomposition belonging to Habitat Type 9110 (Luzulo-Fagetum beech forests). Even though they contain only few vascular plants and mosses, they harbour significant Carpathian-Balkan species (e.g. *Hieracium transsylvanicum* Heuff. [= *Hieracium rotundatum* auct. non Kit.]). Due to this peculiarity, the acid-oligotrophic beech forests of the Carpathians are classified as a separate association at European level (Hieracio rotundati-Fagetum [Vida 1963] Täuber 1987; [Syn: Luzulo-Fagetum auct. Roman.; Fagetum dacicum luzuletosum Beldie 1951; Deschampsio flexuosae-Fagetum Soo 1962]; see Bohn & Bergmeier 2003, Laviniu 2009). They usually grow on acid rocky outcrops with shallow acid brown soil.

The *Picea* forests at higher elevation (Figure 6A; Soldanello majoris-Piceetum, Habitat Type 9410) with dominant *Picea abies* are characterized by *Soldanella major* s.l. a narrow-range species of Alpine-Carpathian distribution (Figure 3). According to Ciocârlan

Figure 3 Biogeographically important plants

Note. A-C Carpathian and Carpathian-Balkan elements of mid-montane forests are: *Symphytum cordatum, Dentaria glandulosa* and *Pulmonaria rubra* (Photos: H. Walentowski). D: *Soldanella major* s.l., the eponymous species for Carpathian high-elevation spruce forests (Photo: H. Walentowski), E: *Bruckenthalia spiculifolia*, commonly known as Spike Heath, is native to rocky grasslands in the Eastern Alps, Carpathians and Balkans (Photo: E.D. Schulze). F: *Myricaria germanica*, a key species of natural and near-natural watercourses of the Alpine region (Photo: E.D. Schulze).

(2009) *Soldanella major* s.l. comprises several microspecies (incl. *Soldanella hungarica* Simonk., *S. marmarossiensis* Kldst., *S. oreodoxa* L.B. Zhang), which evolved during different cycles of range expansion and contraction during late Quaternary climate changes. With 16 microspecies (Zhang et al. 2001), *Soldanella* is an example of high-mountain endemism.

Due to accumulation of raw humus the *Picea* forests contain indicator species of the "billberry-group" (II.1: *Dicranum scoparium, Pleurozium schreberi, Vaccinium myrtillus*), the "hard fern group" (III.1: *Blechnum spicant*, *Luzula sylvatica, Plagiothecium undulatum. Ptilium crista-castrensis)* and the "woodsorrel group" (III.2: *Dryopteris carthusiana, Homogyne alpina, Oxalis acetosella*; numerical codes of the groups according to Figure 2).

The upper elevation of the Carpathian mountains has been deforested for centuries and is covered by acidophilous grasslands (Figure 6; Violo declinatae-Nardetum Simon 1966), which are priority habitat types at European scale (Type 6230*). Characteristic species are *Viola declinata, Potentilla ternata, Gentiana acaulis, Geum montanum*, and the grasses *Anthoxanthum alpinum, Deschampsia flexuosa* and *Nardus stricta*. Ecotonal edges to the surrounding spruce forests are characterized by Habitat Type 4060 (Alpine and Boreal heaths, including the Junipero-Bruckenthalietum Horvat 1936, Figure 3E). Semi-natural high-mountain grasslands and heaths provide important refugia for a relict glacial flora of arctic-alpine distribution as well as for Carpathian endemics, Carpathian-Balkan and Alps-Carpathian species (Negrean & Oltean 1989, Stancu 2010).

The geomorphology of the hillsides is formed by numerous wet sites, springs and small streams. Headwater catchments may form conspicuous V-shaped encroachments and canyons (Figure 4A).

Alluvial sites along the headwaters occur upstream of bedrock bars and barriers of coarse woody debris. The often torrential streams are accompanied by up to 3 m tall herbaceous fringe communities (e.g. Petasitetum kablikiani Szafer et al 1926) enjoying good water and nutrient supply (natural organic flotsam). They belong to the Habitat Type 6430 (Figure 4B).

The upper courses of the rivers Leul and Topolog are accompanied by narrow bands of alluvial *Alnus* forests (Figure 2: Telekio speciosae-Alnetum incanae (Coldea 1986) 1991) which belong to the priority habitat type 91E0* of Annex I of the Habitats Directive. Early successional species are the grey alder (*Alnus incana*) and willows (*Salix caprea*). With ongoing succession *Acer pseudoplatanus, Ulmus glabra* and *Picea* follow. The watercourses remain bordered by tall herbaceous vegetation (LRT 6430). Boia Mare Tamarisk grows on sandy portions of the gravel banks (Figure 3F) (Habitat Type 3230).

Rock faces, hillside debris and stream debris flank the mountain streams harbouring numerous species, which are specialized at growing on rocky slopes (e.g. *Saxifraga cuneifolia, Valeriana tripteris*). The habitat complexes comprise Annex-I-habitat types like siliceous rocky slopes with vegetation specialized at growing on rocky cracks (8220), and ravine forests (Tilio-Acerion, 9180*). The Topolog Canyon may even harbour autochthonous spruce growing on scree fans (Leucanthemo waldsteinianae-Piceetum Krajina 1933, Habitat Type 9410).

Tree species and structural diversity

The following community description is based on regional observations, which will be supplemented and quantified by a grid-based forest inventory as presented in the third section .

The beech forests of Boişoara are not pristine. However, they are embedded in a large, un-dissected forest region. The remoteness and inaccessibility of the area with steep slopes and ravines, and the complete predator-prey pyramid provide the basis for the development and persistence of a long-term habitat tradition and

Figure 4 Mountain valleys

Note. A: V-shaped forest streams of the Boisoara Forest (Photo: H. Walentowski). B: Hydrophilous tall herb fringe communities (Habitat type 6430 (Photo: E.D. Schulze).

ecological structures. The forest communities are close to natural. Particularly the midmontane zone of mixed mountain forests (Table 1) exhibits several canopy strata with a high contribution of *Abies* growing in the deep shade of the lower canopy. If *Abies* does eventually reach the upper canopy it may reach a height of 50 m overtopping *Fagus* by more than 10 m.

Only above 1500 m a.s.l. (subalpine coniferous forest belt), *Picea* forests are considered to be near-natural. Extensive *Picea* stands at lower elevation (1300-1500 m a.s.l., upper montane zone) appear to be of anthropogenic origin having been planted or formed as a succession following sheep grazing. At a similar elevation on neighbouring mountains, the monoculture of *Picea* is not as prominent as in Boişoara forest. Admixed individuals of *Fagus* and *Abies* indicate that a mixed mountain forest might be more natural.

Most *Fagus* and *Picea* stands in Boişoara are up-growing stands probably younger than 140 years. Successional stands have a high abundance of *Betula pendula* and *Populus tremula* (initial phase). The medium phase of succession contains tall stands of relatively low density. *Fagus* stands more than 200 years old are rare and in a stage of decline (regeneration phase).

Deadwood is surprisingly rare, except for sites with age-related decline, even though trees with rotting trunks, broken crowns and canopy dieback are frequent. Former grasslands can be detected by heavily branched trees, which have grown up as isolated individuals. The large number of butt-rotted hollow trees appears to be related to damage caused by former thinning operations and local ground fires. Conspicuous veteran trees are scattered over the whole area of the beech forests. The largest observed stems of *Fagus* have a diameter at breast height (DBH) of 115.5 cm and 40 m height (Figure 2, Suppl. material), *Acer pseudoplatanus* have a DBH of 113 cm and *Abies* have a DBH of 145 cm and a height of 50 m. The regeneration, except for *Acer*, shows little damage by browsing.

Even though the origin of the high-elevation spruce is unclear (reforesting of alpine pastures), the populations in inaccessible canyon-like valleys deserve special attention. Studies on allele length polymorphism designate several glacial refugia for *Picea* in the Southern Carpathian Mountains (Magyari et al. 2011), but infer only limited expansion from these refugia after the last glaciation. Several unique cpDNA and mitochondrial DNA (mtDNA) haplotypes suggested long-lasting isolation (Bucci & Vendramin 2000, Tollefsrud et al. 2008).

Most *Picea* stands are about 100 years old. There is a large number of trees with rotten stems, broken tops, canopy dieback and bizarre forms (e.g. heavily branched trees, Figure 5A) originating from isolated trees growing in pastures. Multiple stems of *Picea* are further indicators of former grassland originating from clumps of browsed regeneration (Figure 5B and Figure 6).

The 80 to 100 year old *Picea* stands are dense, bare of ground vegetation and featuring low abundance of coarse woody debris (Figu-re 5C). In contrast, high amounts of downed logs are accumulated in small ravines (Figure 5D) indicating lateral transport probably after snowmelt. The regeneration of *Picea* shows very little damage except where sheep and goats have entered into the forest. Regeneration of *Picea* on top of coarse woody debris is frequent. Also, regeneration is more frequent in the shelter of fallen trees indicating effects of deer browsing despite the low deer population density.

The grassland communities of the alpine pastures show remarkable micropatterns and ecotones. Young *Picea* trees germinate on mineral soil exposed by digging by wild boar or from animal hoofs; these are heavily grazed and form Bonsai structures (Figure 6A).

Wind-exposed, snow free ridges on shallow Regosols are covered with arctic-alpine lichens (*Cetraria cucullata*). 20 to 30 cm high hemispheric ant mounds are conspicuous structures in *Nardus* grasslands; they have been described for other siliceous mountain ranges (e.g., Schwabe-Kratochwil 1980 for the Black Forest / Southwest Germany) (Figure 6B).

Disturbances

Thinning operations and skidding of long-wood with tractors have caused major damage to remaining stems (Figure 7A). These remaining trees were usually not major canopy trees but formerly suppressed trees of the sub-canopy. Skidding of long-wood with uncut crowns

Figure 5 Spruce forests

Note. A-C: Conspicuous structures of cultivated spruce stands, resulting from secondary forests regenerating from pastures (for early successional stages, see Fig. 6A). A: Heavily branched “open grown” spruce trees (Photo: E.D. Schulze). B: Multitrunk trees, to be considered to be a cluster of individuals trees, C: bare ground stage of 80 to 100 yr old stands (Photo: E.D. Schulze). D: wood accumulation in headwater streams (Photo: E.D. Schulze).

Figure 6 Habitat structures of semi-natural mountain pastures, framed by natural spruce forests

Note. A: Pygmy and heavily browsed spruces try to occupy the recent pasture land (Photo: W. Schulze). B: Hemispherically shaped anthills protrude the surrounding grass level (Photo: H. Walentowski).

caused major erosion affecting water quality. Felling operations may have lasted until after bud break.

Besides disturbances due to wood extraction, there is visible damage by deer, despite the presence of free roaming bears and wolves. Acer pseudoplatanus and Euonymus latifo-*lia* are generally browsed at the terminal bud (Figure 7B). This damage would promote the regeneration of uniform *Fagus* stands. Fraying of *Abies* is abundant.

Additional anthropogenic disturbance is the grazing of forest stands by goats, sheep, cows, donkeys and horses in the vicinity of the grassland and during their migration in spring and autumn from the valley to the mountain meadows (Figure 7C).

The main disturbance to headwaters is the sediment flow from surface erosion following forest operations, and the construction of dams for hydropower in the area, but not on this property.

Figure 7 Anthropo-zoogenetic pressure

Note. A: Skidding damage, skidding of long wood (Photo: E.D. Schulze). B: Browsing damage to *Acer pseudoplatanus* (Photo: E.D. Schulze). C: Grazing of sheep in spruce forest (Photo: E.D. Schulze).

Bioindicators for habitat and environmental quality

In beech forests (Habitat Types 91V0 and 9110), conservation efforts should not only be targeted at the dominant *Fagus* but also at other rare tree genera. A successful rejuvenation of admixed species in beech forests and the associated successional communities across forested landscapes is an indicator of the intactness and completeness of a beech forest ecosystem (Schulze pers. com.). Examples of such associated species are the pioneer trees (*Betula, Populus*), later successional species (e.g., *Acer pseudoplatanus, Carpinus betulus, Prunus avium*), and the late successional *Abies alba*.

Some indicator species reveal the age of the habitat, its structural diversity and habitat longevity, and the environmental quality. The saproxylic beetle *Xestobium austriacum* indicates autochthonous *Abies* habitats. It is confined to very old trees with large stems. In Germany this beetle is classified as “relict

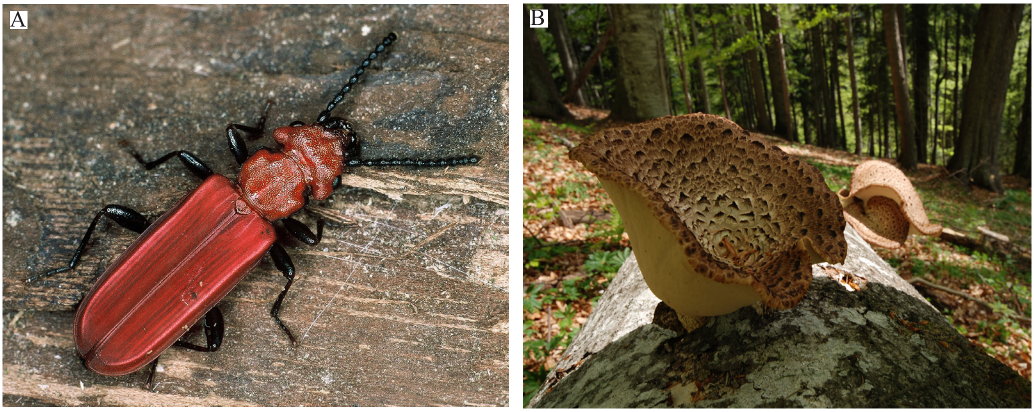


Figure 8 Selected indicator species of habitat and environmental quality

Note. A: *Cucujus cinnaberinus*. The species needs open spaces and prefers lowland areas with soft-wooded broadleaves. The adults and older stages of larvae hibernate under bark on the deadwood. In Romania larvae develop under very decayed bark of aspen *Populus tremula* trees with the fungi *Aspergillus, Trichoderma, Ceratocystis* etc. (Photo: H. Bußler). B: The fungus *Polyporus squamosus* has a widespread distribution, being found in North America, Australia, Asia, and Europe, where it causes a white rot in the heartwood of living and dead hardwood trees (Photo: A. Heßberg). C: The foliose lichen *Lobaria pulmonaria*, commonly known as lungwort or lung lichen. Due to declining population, *L. pulmonaria* is considered to be rare or threatened in many parts of the world, especially in lowland areas of Europe (Photo: H. Walentowski).

of lost virgin forests" (Müller et al. 2005a). *Bolitophagus reticulatus* is a beetle of montane forests associated with the fungus *Fomes fomentarius* on *Fagus* and *Betula*. *Cucujus cineraberinus* (Figure 8A) lives as larvae under the bark of wet coarse deadwood mainly of *Populus tremula*. The rare fungus *Polyporus squamosus* (Figure 8B) grows on coarse woody debris causing white rot, while the lichen *Lobaria pulmonaria* (Figure 8C) that indicates low air pollution, has almost been eliminated from central Europe.

In spruce forests (Habitat Type 9410) the following taxonomic groups and species are indicators for habitat quality and intact environmental conditions: epiphytic lichen species, e.g. *Bryoria, Evernia, Pseudevernia, Hypogymnia* and *Usnea,* require high air quality. The red rove beetle *Olisthaerus substriatus* is a typical indicator for older Norway spruce forests (Jönsson et al. 2011) living predatorily under the bark of old *Picea* trees. This species lives in the boreal and the alpine region. In Germany this rove beetle (family *Staphylinidae*) is considered as relict of lost virgin forest (Müller et al. 2005a).

Indicators for pristine watercourses with intact hydrology, dynamics and water quality of the Habitat Types 3230, 6430, 91E0* include the species ostrich fern (*Matteucia struthiopteris*) which grows in moist soils of deciduous and mixed forest, wooded river bottoms, and swamps. This species is representative of intact alluvial forests that accompany and shelter headwater catchments. Similarly, the German tamarisk (*Myricaria germanica,* Figure 3F) indicates unregulated rivers of the Alpine region. Fish species like *Barbus meridionalis, Cottus gobio* and *Gobio uranoscopus* indicate clean, oxygen-rich, rapid-flowing rivers.

Future management frameworks should have the objective of maintaining these bioindicators.

Forest management: past practices and future orientation

Present wood extraction

The Romanian forest regulations distinguish four types of extraction: hygiene cutting i.e. thinning of stands in the thicket stage to reduce forest pests and diseases; successive cutting, i.e. thinning of pole-stage stands; progressive cutting, i.e. inducing natural regeneration; and conservation cutting, i.e. the final cut. The final cut may leave shelterwood with natural regeneration in *Fagus* or clear cutting and re-planting in *Picea*.

The actual extraction method is constrained by the topography, the technical equipment available for harvest and transport, and the wood market. Trees are generally cut manually by chainsaw and dragged as long-wood by tractors or by a cable-line, with associated damage to the remaining trees and the forest regeneration. There is no network of skidding trails (Figure 3, Suppl. material).

The wood market is the dominant control on the harvest. *Fagus* is cut at a diameter below 50 cm because more than 80% of the wood has low quality and will be sold as firewood or for chipboard. Other hardwoods (e.g. *Acer*) receive higher prices than *Fagus*, but require large diameters. Coniferous wood receives a higher price than hardwood Heavily branched stems with large diameter are uneconomic to fell. *Abies* sells for a 10% lower price than *Picea*.

Most wood is sold in bulk, with the sawmill, rather than the forest owner, sorting the wood into merchantable assortments of different wood quality. The lack of machinery and the business structure encourages the transport of timber from the site to the forest road as long-wood, with the associated devastating effects on soils, regeneration and remaining trees. The whole operation from cutting to sawing is in the hands of single companies. Wood volume is estimated before harvest using general national equations without sorting the stems according to lumber quality on the basis of a management plan. The forest engineers mark the block, where the cutting takes place but do not oversee the harvest operation. Thus, the operator cuts more than was initially estimated (1 to 10% of the felled trees were found unmarked). This whole system favours clear-cutting, or there are major damages to the remaining stand.

Given these constraints, with current forestry practice the final harvest is inevitably restricted to clear-cutting. It is a type of "cut and go" technology dictated by sawmills. In mixed stands, the cuttings are more progressive with a focus on coniferous species, which results in an apparent rise in elevation of the border between deciduous and coniferous forests.

Considerations for future management

Future forest management should be ecologically sustainable in view of the existing fauna and flora, but it must also be economic in view

Table 3 Management of *Fagus* and *Picea* forest as related to slope

Slope	*Fagus* forest	Mixed alpine forest	*Picea* forest
0 to 20°	Selection cutting by target diameter	Selection cutting by target diameter	Balanced selection cutting
20 to 35°	Gap regeneration	Gap regeneration	Stripe regeneration
> 35°	Protection forest	Protection forest	Protection forest

of harvesting cost and wood sales. Here we consider management schemes in relation to terrain and tree species (Table 3).

Future management must use harvester and forwarder technology. The present situation of cutting trees only within reach of easy skidding is unacceptable. Transport of wood as long-wood must be avoided because of the unacceptable damage to remaining trees and regeneration. Steep slopes should be maintained as a kind of "strict forest reserve" because the steep canyons may be the only places where original genetic resources have been maintained.

Picea forests. On gentle slopes selective logging with conservation of large-dimensioned veteran trees would ensure the habitat continuity and diversity needed to maintain rare species. Special forest sites, such as springs should remain untouched. The proposed management would be characterized by medium-intervention in beech-spruce forest, and high intervention in Norway spruce, as suggested by Duncker et al. (2012).

Selective logging, while maintaining permanent forest cover, becomes technically impossible on steep slopes, where the transport of single trees causes so much damage to the root collar of remaining trees that the stand as a whole is endangered. In this case harvesting on narrow downhill strips can be used; this method is commonly applied in the Alps. Strip cutting also exposes mineral soil promoting the establishment of a wide range of tree species. The forest may change from a *Picea* monoculture into a mixed mountain forest. At present Romanian forest law requires the collection of slash and re-planting, but erosion would decrease if slash were not collected, and local genetic sources would be preserved with natural regeneration. The preservation of veteran trees would support habitat continuity for many organisms such as the saproxylic beetle *Olisthaerus substriatus*. The slash and the root stocks should ensure a deadwood store of >30 m^3 ha^{-1}, which is important in cool forests (Lachat et al. 2012). A number of ascertained bird species (Supplement Table S4) would also be promoted by strip harvesting, such as the capercaillie (*Tetrao urogallus*), the hazel grouse (*Bonasia bonasia*) and the red-throated flycatcher (*Ficedula parva*) which prefer forest margins because of higher occurrence of *Vaccinium*. Forest management reaches a natural limit at slopes >35°, and these sites must remain un-managed.

Fagus forests. On gentle slopes selective logging by target diameter with the maintenance of veteran trees appears ecologically the most sustainable option. The proposed management would be a low-intervention type as proposed by Duncker et al. (2012). The creation of a heterogeneous light regime by combining gap and shelterwood cutting would allow early and late successional species to regenerate, including *Populus* and *Betula*. At the same time *Abies* would be promoted under dense canopies and *Acer* under semi-open canopies. This type of management would also ensure the habitats for a range of endangered saproxylic beetle species (Bouget pers. comm.) such as *Morimus funereus, Cucujus cinnaberinus, Bolitophagus reticulatus* and *Xestobium austriacum*.

An example of a novel grid-based inventory

The Romanian management plan or "amenajament" contain average data without an indication of their variation. These numbers are not sufficient for detailed planning of specific operations. Only grid-based inventories, measuring each tree within a prescribed area, can quantify the uncertainty in variables. We therefore established an example 200 x 200 m grid on a mountain plateau, in Boişoara forest. The site was above 1500 m elevation. The grid was comprised of 45 circles of 1000 m^2, which is statistically marginally sufficient for inventory purposes. Within these circles, all trees were mapped and breast height diameter and tree height were measured. In addition both bole quality and damages to trees were

Table 4 Forest inventory data and analysis of high-elevation spruce forest of the Boişoara forest based on 45 inventory plots of $1000m^2$ per plot

DBH (cm)	Density (trees per ha)	Basal area (m^2 ha^{-1})	Wood volume (m^3 ha^{-1})	Option 1 Thinning from top		Option 2 Thinning from below		Option 3 Thinning balance	
				Remaining density (trees ha^{-1})	Remaining volume (m^3 ha^{-1})	Remaining density (trees ha^{-1})	Remaining volume (m^3 ha^{-1})	Remaining density (trees ha^{-1})	Remaining volume (m^3 ha^{-1})
0-10	249	1.2	4.1	249		249		249	
10-20	466	8.8	46.4	40		80	8	80	8
20-30	315	15.2	102.1	31	4	99	32	99	32
30-40	150	13.1	98.6	15	10	32	21	32	21
40-50	57	8.9	62.1	56	10	8	9	27	30
50-60	15	3.7	23.2	15	62	5	7	10	15
60-70	3	0.9	5.2	3	23	5	5	5	1
70-80	1	0.2	1.2	1		1		1	
Tracks					12		12		12
Total	1254	51.9	343.1	410	121	479	94	503	121

recorded. Regeneration density and deadwood was quantified.

Table 4 summarizes the data giving the range of tree densities, basal areas, and wood volumes per ha of the 45º slope-corrected inventory circles. Total tree density at elevations above 1500 m is about 1200 trees per ha with a basal area of about 52 m^2 ha^{-1}, and a wood volume of about 340 m^3 ha^{-1}. Tree height reaches a maximum of about 30 m, but average top height is about 22 m.

A pre-requisite for any forest operation is a network of tracks to ensure that the machines operate only on prescribed paths. Thus hauling or skidding tracks of 4 m width and 30 m apart, at right angles to the main howling path need to be established. Based on our inventory data, this operation would yield about 12 m^3 ha^{-1} of wood, irrespective of diameter. The wood extraction between the tracks largely depends on the price for industrial wood which contributes about 50% of the total harvest. Trees above 60 cm diameter should not be harvested unless they root on the skidding track. De-branching of the former isolated trees would be uneconomic.

Based on the inventory data various thinning schemes can now be planned. The highest commercial value would be achieved by "thinning-from-the-top", i.e., extracting trees with diameter of 40 to 60 cm because this diameter class will only lose economic value with further growth. The main disadvantage of this operation would be the large amount of damage done to the remaining trees. Further, it would also not extract badly formed and distorted sub-canopy trees. The total amount of wood, which would be extracted by thinning-from-the-top would total about 120 m^3 ha^{-1}, which would be 30% of the standing crop.

In a second scenario, "thinning-from-below", a plot of 1 ha was marked to support the dominating trees by reducing competition with minor trees. In this approach, only about 95 m^3 ha^{-1} would be harvested (Table 4), and most of the large trees remain.

In a third scenario, "balanced-thinning", the low diameter trees would still be extracted as above, but 50% of the 40 to 50 cm diameter class and 75% of the 50 to 60 cm diameter class would also be thinned. In this way, the canopy structure and tree-size distribution would be maintained. In this case, the felling would total about 120 m^3 ha^{-1}, the same as with the thinning-from-the-top method.

In order to establish a sustainable Natura

2000 management plan a number of additional administrative and structural changes appear necessary. The current Management plan ("amenajament") should be replaced by grid-based inventories. An infrastructure of forest roads suitable for trucks must be provided to avoid long distance skidding of long-wood with its associated damage. Harvesting and hauling must use harvester and forwarder technology based on short-wood, and not tracktors skidding long-wood.

Training in applying these new methods and technologies will be needed for all forest workers, and for most forest engineers. Most likely, their salaries will then need to be raised to avoid trained personnel migrating to other EU countries. Start-up money will be needed for small independent companies specialized in harvesting, thinning, tending, planting and other forest works.

The hunting regime must change from the Ceauşescu heritage of large game reserves, which encourage "legalized" poaching (i.e. selling unknown numbers of trophies) to smaller management units. The level of hunting should be determined as part of an integrated management plan which balances silvicultural need with the demands of hunters. It is no longer acceptable that hunters claim the wild life as their property, while the forest owners suffer the consequences of browsing damage without legal right for hunting.

The degree of ecological damage caused by clear-cutting remains an open question. Clear-cuts do not necessarily destroy the forest ecosystem. Looking at the effects of large scale clear-cutting after World War I and II and at the effects of large scale wind throws (Don et al. 2012) which were taking place on this property, clear cuts in temperate forests may not be ecologically as damaging as it is claimed. Regenerating forest on clear-cut land had the highest tree diversity in Thuringia (Schulze pers. com.). The presence of indicator species representing un-managed forest show that clear-cutting had no long-lasting effect, if it was a "cut-and-go" operation. Probably diversity is lost during thinning.

Conclusions

The diversity of the Carpathian forests is very high and contains a large number of relicts of unmanaged forest even at the scale of 500 ha and even though the area has undergone intensive management in the past. Management and wood extraction is needed to provide income to pay the costs of supervision of the state forest; the present far-reaching governmental controls, which provide limited services, are not fit-for-purpose and should be abandoned. Long periods without human interference (following cut-and-go) may be the secret of the high biological diversity of the Carpathian Mountains. However, this may not be a realistic option for the future and a better course of action would be the promotion of management plans based on a foundation of grid-based inventories. This would allow planning to take account of all the economic and ecological constraints. A pilot study is needed to demonstrate and promote modern integrated forest management as the best way of maintaining biological diversity in this Natura 2000 region.

Acknowledgements

We greatly acknowledge the help of Annett Boerner in drawing of Fig. 1 and 3, and of Dr John Gash to edit our English. We also acknowledge the help of Uli Pruschitzki and Angela Günther who carried out most of the field work of the grid-based inventory. O.B. and M.T. were supported by a grant of the Romanian National Authority for Scientific Research, CNCS-UEFISCDI, project number PN-II-ID-PCE-2011-3-0781

Additionally, we would like to thank the following people for their contributions to this study: Tim Besser, Iulian Straut and Otilia Mazilu. We thank Martin Kaiser for fruitful discussions about forest management.

References

BirdLife European Forest Task Force, 2009. Bulgarian-Romanian Forest Mapping Project, final report, 69 p. Web:http://www.hcvnetwork.org/resources/assessments/BRFM%20report_English_low%20resolution.pdf Accessed: 09.11.2012.

Bohn U., Bergmeier E., 2003. Formation F.5 (Beech forests and beech mixed forests). In: Bohn et al. Map of the natural Vegetation of Europe. Part 1: Explanatory Text with CD-ROM. Federal Agengy for Nature Conservation, Bonn, pp. 310-344.

Borza A., Boşcaiu N., 1965. Introducere în studiul covorului vegetal [Introduction on the study of the vegetal covers]. Editura Academiei Române, Bucureşti, 340 p.

Bouriaud L., Marzano M., 2012. Conservation, extraction and corruption: will sustainable forest management be possible in Romania? In: Gilberthorpe, E. (ed.), Natural resource extraction and indigenous livelihoods: development challenges in an era of globalisation, Ashgate International.

Bucci G., Vendramin G.G., 2000. Delineation of genetic zones in the European Norway spruce natural range: preliminary evidence. Molecular Ecology 9: 923-934.

Ciocârlan V., 2009. Flora illustrata a României: Pteridophyta et Spermatophyta [Romanian ilustrated flora: Pteridophyta et Spermatophyta]. Ceres, Bucureşti, 1141 p.

Coldea G., 1991. Prodromme des associations végétales des Carpates du sud-est (Carpates roumains) [Prodrom of the vegetal associations from south-east Carpathians]. Doc. Phytosociol., N.S. 13: 317-539.

Coldea G., 2000. Southeastern Carpathians / Tatra Mountains. In: Burga C.A., Klötzli F., Grabherr G. (eds.): Mountains of the world. Ulmer, Stuttgart, pp. 104-114.

Don A., Bärwolff M., Kalbitz K., Andruschkewitsch R., Jungkunst H.F., Schulze E.D., 2012. No rapid carbon loss after a wind throw event in the High Tatra. Forest Ecolology and Management 276: 239-246.

Duncker P.S., Raulund-Rasmussen K., Gundersen P., Katzensteiner K., De Jong J., Ravn H.P., Smith M., Eckmüllner O., Spieker H., 2012. How forest management affects ecosystem services, including timber production and economic return: Synergies and trade-offs. Ecology and Society 17(4): 50.

EEA (European Environment Agency), 2006. Factsheet Munţii Făgăraş. Web: http://eunis.eea.europa.eu/sites/ROSCI0122/general. Accessed: 30.10.2012.

EEA (European Environment Agency), 2012. Biogeographic regions in Europe. Web: http://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-1. Accessed: 04.02.2013.

Ewald J. 2007. Ecogram of forest plants indicator species. Web: http://www.hswt.de/uploads/media/Oekogramm_lateinisch.pdf. Accessed: 22.10.2012.

Gafta D., Mountford O., 2008: Manual de interpretare a habitatelor Natura 2000 din România. [Manual of interpretation for Natura 2000 Habitats from Romania]. Risoprint, Cluj-Napoca. 101 p. Web: http://www.coastal-biodiv.ro/docs/manual_de_interpretare_a_habitatelor.pdf. Accessed: 30.10.2012.

Jönsson M.T., Fraver S., Jonsson B.G., 2011. Spatio-temporal variation of coarse woody debris input in woodland key habitats in central Sweden. Silva Fennica 45(5): 957-967.

Lachat T., Wermelinger B., Gossner M.M., Bussler H., Isacsson G., Müller J., 2012. Saproxylic beetles as indicator species for dead-wood amount and temperature in European beech forests. Ecological Indicators 23: 323-331.

Laviniu B., 2009. Phytocoenological and ecological study of beech forests from Pădurea Craiului Mountains (North-Western Romania, Bihor County). Analele Universităţii din Oradea, Fascicula Protecţia Mediului 14: 441-446.

Magyari E.K., Major A., Bálint M., Nédli J., Braun M., Rácz I., Parducci L., 2011. Population dynamics and genetic changes of *Picea abies* in the South Carpathians revealed by pollen and ancient DNA analyses. BMC Evolutionary Biology 11: 66.

Mayer H., 1984. Wälder Europas [Forests of Europe]. G. Fischer, Stuttgart, 691 p.

Moning C., Bußler H., Müller J., 2009. Ökologische Sc hlüssel werte in Bergmisc ergmisc hwäldern als Grun dlage für eine nac hhaltige Forst wirtsc haft [Ecological key values in mixed montane forests as basis for sustainable forestry]. Bavarian Forest National Park Scientific Series 19, Grafenau, 103 p.

MCPFE (Ministerial Conference on the Protection of Forests in Europe), 2003. Improved Pan-European Indicators for Sustainable Forest Management as adopted by the MCPFE Expert Level Meeting 7-8 October 2002, Vienna, Austria. Web: http://www.foresteurope.org/documentos/improved_indicators.pdf. Accessed: 17.02.2013.

Moravec, J. 1985. Chorological and ecological phenomena in the differentiation and distribution of the *Fagion* associations in Bohemia and Moravia (Czechoslovakia). Vegetatio 59: 39-45.

Müller J., Bußler H., Bense U., Brustel H., Flechtner G., Fowles A., Kahlen M., Möller G., Mühle H., Schmidl J., Zabransky P., 2005a. Urwald relict species - Saproxylic beetles indicating structural qualities and habitat tradition - Urwaldrelikt-Arten - Xylobionte Käfer als Indikatoren für Strukturqualität und Habitattradition. Waldökologie online 2: 106-113.

Müller J., Strätz C., Hothorn T., 2005b. Habitat factors for land snails in European beech forests with special focus on coarse wood debris. European Journal of Forest Research 124: 233-242.

Negrean G., Oltean M., 1989. Endemite şi zone endemo-

conservatoare din Carpații S-E [Endemics and conservation areas from the SE Carpathians]. Ocrotirea Naturii şi a Mediului Înconjurător. . 33 (1): 15-25.
Schwabe-Braun A., 1980. Eine pflanzensoziologische Modelluntersuchung als Grundlage für Naturschutz und Planung [A phyto-sociological model-investigation as basis for nature conservation and planing]. Urbs et Regio 18: 1-212.
Stancu D.I., 2010. The floristic richness of Buda and Râiosu Mountains, Făgăraş massif. Studii şi Comunicări, Ştiinţele Naturii 26 (2): 52-56.
Tollefsrud M.M., Kissling R., Gugerli F., Johnsen O., Skrøppa T., Cheddadi R., Van der Knaap W.O., Latałowa M., Terhürne-Berson R., Litt T., Geburek T., Brochmann C., Sperisen C., 2008. Genetic consequences of glacial survival and postglacial colonization in Norway spruce: combined analysis of mitochondrial DNA and fossil pollen. Molecular Ecology 17: 4134-4150.
Vintilă A., 2012. The anthropogenic potential impact on flora in Ghițu-Moliviş area (Argeş county). Studii şi Comunicări, Ştiinţele Naturii 28(2): 52-56.
Wäldchen J., Schulze E.D., Schöning I., Schrumpf M., Sierra C., 2012. The influence of changes in forest management over the past 200 years on present soil organic carbon stocks. Forest Ecology and Management 289: 243-254.
Wippel B., Becker G., Seintsch B., Rosenkranz L., Englert H., Dieter M., Möhring B., Stratmann J., Gerst J., Paschke M., Riedinger D., 2013. Project FFH-Impact: Implementing the Habitats Directive in German forests. - Executive summary of a case study on the economic and natural impacts on forest enterprises. Thünen-Institute of Forest Based Sector Economics, Hamburg, 34 p. Web.: http://www.ti.bund.de/fileadmin/dam_uploads/vTI/Bilder/Aktuelles/Downloads_2013/FFH-Impact_Executive%20Summary%20english_.pdf. Accessed: 17.02.2013.
Zhang L.B., Comes H.P., Kadereit J.W., 2001. Phylogeny and quaternary history of the European montane/alpine endemic *Soldanella* (*Primulaceae*) based on ITS and AFLP variation. American Journal of Botany 88(12): 2331-2345.

Appendix

Table 1 Habitat Classes of the ROSCI0122 Munții Făgăraş

Habitat Class	% of land area
Heath, Scrub	12
Dry grassland, steppe	10
Broad leaved deciduous woodland	18
Coniferous woodland	25
Mixed forest	32
Rock faces, Screes, Sands, Snow, Ice	3
Total habitat cover	100

Note. Source: Natura 2000 standard data form (http://natura2000.eea.europa.eu/Natura2000/SDFPublic. aspx?site=ROSCI0122#4).

Table 2 Important habitats according to Annex I of the EC Habitats Directive in the Natura 2000 area ROSCI0122 Munții Făgăraş

Code	Cover (%)	Repre-sentativity (i)	Relative surface (ii)	Conservation Status (iii)	Global assessment (iv)
6520 - Mountain hay meadows	10.0	B	B	B	B
9110 - Luzulo-Fagetum beech forests	10.9	A	B	B	A
9410 - Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea)	21.3	A	B	A	A
91V0 - Dacian Beech forests (Symphyto-Fagion)	36.0	A	B	B	A
6230* - Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas	0.1	A	A	A	A
91E0* - Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)	10.0	B	B	B	B

Note. Source: Natura 2000 standard data form. The priority habitats are indicated by an asterisk (*). The assessment results for the criterions (i), (iii) and (iv) mean: A - excellent, B - good, C - significant. For criterion (ii), the ranking is expressed in percentage: A: $100 \geq p > 15\%$, B: $15 \geq p > 2\%$, C: $2 \geq p > 0$.

Table 3 Preliminary list of plant species found in the Boişoara Forest

No.	Plant species	Family
1	*Abies alba*	*Pinaceae*
2	*Acer platanoides*	*Aceraceae*
3	*Acer pseudoplatanus*	*Aceraceae*
4	*Achillea millefolium*	*Asteraceae*
5	*Actaea spicata*	*Ranunculaceae*
6	*Aegopodium podagraria*	*Apiaceae*
7	*Agrimonia eupatoria*	*Rosaceae*
8	*Agrostis canina*	*Poaceae*
9	*Agrostis capillaris*	*Poaceae*
10	*Agrostis gigantea*	*Poaceae*
11	*Agrostis stolonifera*	*Poaceae*
12	*Ajuga reptans*	*Lamiaceae*
13	*Alchemilla vulgaris agg.*	*Rosaceae*
14	*Alliaria petiolata*	*Brassicaceae*
15	*Alnus incana*	*Betulaceae*
16	*Anemone nemorosa*	*Ranunculaceae*
17	*Anemone ranunculoides*	*Ranunculaceae*
18	*Angelica sylvestris*	*Apiaceae*
19	*Antennaria dioica*	*Asteraceae*
20	*Anthoxanthum alpinum*	*Poaceae*
21	*Anthriscus nitida*	*Apiaceae*
22	*Anthriscus sylvestris*	*Apiaceae*
23	*Arctium minus*	*Asteraceae*
24	*Arctium tomentosum*	*Asteraceae*
25	*Arenaria biflora*	*Caryophyllaceae*
26	*Asplenium ruta-muraria*	*Aspleniaceae*
27	*Asplenium scolopendrium*	*Aspleniaceae*
28	*Asplenium trichomanes*	*Aspleniaceae*
29	*Athyrium filix-femina*	*Woodsiaceae*
30	*Atropa bella-donna*	*Solanaceae*
31	*Betula pendula*	*Betulaceae*
32	*Bruckenthalia spiculifolia*	*Ericaceae*
33	*Calamagrostis arundinacea*	*Poaceae*
34	*Calamagrostis epigejos*	*Poaceae*
35	*Callitriche spec.*	*Plantaginaceae*
36	*Calluna vulgaris*	*Ericaceae*
37	*Caltha palustris*	*Ranunculaceae*
38	*Campanula spec.*	*Campanulaceae*
39	*Capsella bursa-pastoris*	*Brassicaceae*
40	*Cardamine amara*	*Brassicaceae*
41	*Cardamine hirsuta*	*Brassicaceae*
42	*Cardamine impatiens*	*Brassicaceae*
43	*Cardamine pratensis*	*Brassicaceae*
44	*Cardaminopsis arenosa* subsp. *borbasii*	*Brassicaceae*

Table 3 (continuation)

No.	Plant species	Family
45	*Carduus acanthoides*	*Asteraceae*
46	*Carduus personata*	*Asteraceae*
47	*Carex canescens*	*Cyperaceae*
48	*Carex caryophyllea*	*Cyperaceae*
49	*Carex cf strigosa*	*Cyperaceae*
50	*Carex digitata*	*Cyperaceae*
51	*Carex ligerica*	*Cyperaceae*
52	*Carex pendula*	*Cyperaceae*
53	*Carex pilulifera*	*Cyperaceae*
54	*Carex remota*	*Cyperaceae*
55	*Carex sylvatica*	*Cyperaceae*
56	*Carlina acaulis*	*Asteraceae*
57	*Carpinus betulus*	*Betulaceae*
58	*Centaurea jacea*	*Asteraceae*
59	*Cepahlaria pilosa*	*Caprifoliaceae*
60	*Cerastium fontanum*	*Caryophyllaceae*
61	*Chaerophyllum bulbosum*	*Apiaceae*
62	*Chaerophyllum hirsutum*	*Apiaceae*
63	*Chaerophyllum temulum*	*Apiaceae*
64	*Chelidonium majus*	*Papaveraceae*
65	*Chenopodium album*	*Amaranthaceae*
66	*Chenopodium bonus-henricus*	*Amaranthaceae*
67	*Chrysosplenium alternifolium*	*Saxifragaceae*
68	*Cicerbita alpina*	*Asteraceae*
69	*Cirsium arvense*	*Asteraceae*
70	*Cirsium erisithales*	*Asteraceae*
71	*Cirsium oleraceum*	*Asteraceae*
72	*Cirsium palustre*	*Asteraceae*
73	*Clinopodium vulgare*	*Lamiaceae*
74	*Corallorrhiza trifida*	*Orchidaceae*
75	*Cornus sanguinea*	*Cornaceae*
76	*Corydalis solida*	*Fumariaceae*
77	*Corylus avellana*	*Corylaceae*
78	*Crocus vernus*	*Iridaceae*
79	*Cruciata glabra*	*Rubiaceae*
80	*Cruciata laevipes*	*Rubiaceae*
81	*Cynoglossum officinale*	*Boraginaceae*
82	*Cystopteris fragilis*	*Athyriaceae*
83	*Dactylis glomerata*	*Poaceae*
84	*Daucus carota*	*Apiaceae*
85	*Dentaria bulbifera*	*Brassicaceae*
86	*Dentaria glandulosa*	*Brassicaceae*
87	*Deschampsia cespitosa*	*Poaceae*
88	*Deschampsia flexuosa*	*Poaceae*
89	*Digitalis grandiflora*	*Scrophulariaceae*
90	*Doronicum austriacum*	*Asteraceae*
91	*Dryopteris affinis*	*Athyriaceae*
92	*Dryopteris carthusiana*	*Athyriaceae*
93	*Dryopteris dilatata*	*Athyriaceae*
94	*Dryopteris filix-mas*	*Athyriaceae*
95	*Eleocharis palustris*	*Cyperaceae*
96	*Elymus repens*	*Poaceae*
97	*Epilobium angustifolium*	*Onagraceae*
97	*Epilobium parviflorum*	*Onagraceae*
98	*Epilobium roseum*	*Onagraceae*
99	*Equisetum arvense*	*Equisetaceae*
100	*Equisetum hyemale*	*Equisetaceae*
101	*Equisetum palustre*	*Equisetaceae*
102	*Equisetum telmateia*	*Equisetaceae*
103	*Erigeron annuus*	*Asteraceae*
104	*Eriophorum vaginatum*	*Cyperaceae*
105	*Euonymus latifolia*	*Celastraceae*
106	*Eupatorium cannabinum*	*Asteraceae*

No.	Plant species	Family
107	*Euphorbia amygdaloides*	*Euphorbiaceae*
108	*Euphorbia cyparissias*	*Euphorbiaceae*
109	*Fagus sylvatica*	*Fagaceae*
110	*Festuca drymeja*	*Poaceae*
111	*Festuca gigantea*	*Poaceae*
112	*Festuca rubra*	*Poaceae*
113	*Fragaria vesca*	*Rosaceae*
114	*Fraxinus excelsior*	*Oleaceae*
115	*Gagea minima*	*Liliaceae*
116	*Galeobdolon montanum*	*Lamiaceae*
117	*Galanthus nivalis*	*Amaranthaceae*
118	*Galeopsis tetrahit*	*Lamiaceae*
119	*Galium kitaibelianum*	*Rubiaceae*
120	*Galium odoratum*	*Rubiaceae*
121	*Galium palustre*	*Rubiaceae*
122	*Galium pseudoaristatum*	*Rubiaceae*
123	*Gentiana asclepiadea*	*Gentianaceae*
124	*Gentiana acaulis*	*Gentianaceae*
125	*Gentiana pneumonanthe*	*Gentianaceae*
126	*Geranium pyrenaicum*	*Geraniaceae*
127	*Geranium robertianum*	*Geraniaceae*
128	*Geum montanum*	*Rosaceae*
129	*Geum urbanum*	*Rosaceae*
130	*Glechoma hederacea*	*Lamiaceae*
131	*Glechoma hirsuta*	*Lamiaceae*
132	*Glyceria fluitans*	*Poaceae*
133	*Gnaphalium sylvaticum*	*Asteraceae*
134	*Gymnocarpium dryopteris*	*Athyriaceae*
135	*Heracleum sphondylium*	*Apiaceae*
136	*Hieracium transsylvanicum*	*Asteraceae*
137	*Holcus lanatus*	*Poaceae*
138	*Homogyne alpina*	*Asteraceae*
139	*Hordelymus europaeus*	*Poaceae*
140	*Hypericum hirsutum*	*Hypericaceae*
141	*Hypericum perforatum*	*Hypericaceae*
142	*Hypericum tetrapterum*	*Hypericaceae*
143	*Hypochaeris radicata*	*Asteraceae*
144	*Impatiens noli-tangere*	*Balsaminaceae*
145	*Juncus alpinoarticulatus*	*Juncaceae*
146	*Juncus articulatus*	*Juncaceae*
147	*Juncus effusus*	*Juncaceae*
148	*Juncus tenuis*	*Juncaceae*
149	*Juniperus sibirica*	*Cupressaceae*
150	*Lamium album*	*Lamiaceae*
151	*Lamium maculatum*	*Lamiaceae*
152	*Lapsana communis*	*Asteraceae*
153	*Lastrea limbosperma*	*Polypodiaceae*
154	*Lathraea squamaria*	*Scrophulariaceae*
155	*Lathyrus pratensis*	*Fabaceae*
156	*Lathyrus tuberosus*	*Fabaceae*
157	*Lilium martagon*	*Liliaceae*
158	*Lolium perenne*	*Poaceae*
159	*Lunaria rediviva*	*Brassicaceae*
160	*Luzula luzuloides*	*Juncaceae*
161	*Luzula pilosa*	*Juncaceae*
162	*Luzula sylvatica*	*Juncaceae*
163	*Lychnis spec.*	*Caryophyllaceae*
164	*Lycopodium annotinum*	*Lycopodiaceae*
165	*Lysimachia nummularia*	*Primulaceae*
166	*Malus spec.*	*Rosaceae*
167	*Matteuccia struthiopteris*	*Athyriaceae*
168	*Medicago lupulina*	*Fabaceae*
169	*Mentha longifolia*	*Lamiaceae*

Table 3 (continuation)

No.	Plant species	Family
170	*Mercurialis perennis*	*Euphorbiaceae*
171	*Milium effusum*	*Poaceae*
172	*Moehringia trinervia*	*Caryophyllaceae*
173	*Monotropa hypophegea*	*Pyrolaceae*
174	*Mycelis muralis*	*Asteraceae*
175	*Myosotis arvensis*	*Boraginaceae*
176	*Myosotis scorpioides*	*Boraginaceae*
177	*Myosoton aquaticum*	*Caryophyllaceae*
178	*Nardus stricta*	*Poaceae*
179	*Neottia nidus-avis*	*Orchidaceae*
180	*Oxalis acetosella*	*Oxalidaceae*
181	*Paris quadrifolia*	*Liliaceae*
182	*Petasites albus*	*Asteraceae*
183	*Petasites hybridus*	*Asteraceae*
184	*Petasites kablikianus*	*Asteraceae*
185	*Phacelia tancetifolia*	*Boraginaceae*
186	*Phalaris arundinacea*	*Poaceae*
187	*Phegopteris connectilis*	*Polypodiaceae*
188	*Picea abies*	*Pinaceae*
189	*Pinguicula vulgaris*	*Lentibulariaceae*
190	*Plantago lanceolata*	*Plantaginaceae*
191	*Plantago major*	*Plantaginaceae*
192	*Platanthera bifolia*	*Orchidaceae*
193	*Poa humilis*	*Poaceae*
194	*Poa nemoralis*	*Poaceae*
195	*Poa pratensis*	*Poaceae*
196	*Poa supina*	*Poaceae*
197	*Poa trivialis*	*Poaceae*
198	*Polygala vulgaris*	*Polygalaceae*
199	*Polygonatum verticillatum*	*Liliaceae*
200	*Polypodium vulgare*	*Polypodiaceae*
201	*Polystichum aculeatum*	*Athyriaceae*
202	*Polystichum braunii*	*Athyriaceae*
203	*Populus tremula*	*Salicaceae*
204	*Potentilla argentea*	*Rosaceae*
205	*Potentilla erecta*	*Rosaceae*
206	*Potentilla ternata*	*Rosaceae*
207	*Primula spec.*	*Primulaceae*
208	*Prunella vulgaris*	*Lamiaceae*
209	*Prunus avium*	*Rosaceae*
210	*Pulmonaria rubra*	*Boraginaceae*
211	*Pyrus communis*	*Rosaceae*
212	*Ranunculus acris*	*Ranunculaceae*
213	*Ranunculus cf. montanus*	*Ranunculaceae*
214	*Ranunculus cf. nemorosus*	*Ranunculaceae*
215	*Ranunculus repens*	*Ranunculaceae*
216	*Rhamnus cathartica*	*Rhamnaceae*
217	*Rosa spec.*	*Rosaceae*
218	*Rubus fruticosus agg.*	*Rosaceae*
219	*Rubus idaeus*	*Rosaceae*
220	*Rumex acetosa*	*Polygonaceae*
221	*Rumex obtusifolius*	*Polygonaceae*

No.	Plant species	Family
222	*Sagina procumbens*	*Caryophyllaceae*
223	*Salicornia fragilis*	*Caryophyllaceae*
224	*Salix caprea*	*Salicaceae*
225	*Salix cinerea*	*Salicaceae*
226	*Salix silesiaca*	*Salicaceae*
227	*Salix triandra*	*Salicaceae*
228	*Salvia glutinosa*	*Lamiaceae*
229	*Sambucus ebulus*	*Caprifoliaceae*
230	*Sambucus nigra*	*Caprifoliaceae*
231	*Sambucus racemosa*	*Caprifoliaceae*
232	*Saxifraga stellaris*	*Saxifragaceae*
233	*Scilla bifolia* subsp. *drunensis*	*Asparagaceae*
234	*Scirpus sylvaticus*	*Cyperaceae*
235	*Scrophularia nodosa*	*Scrophulariaceae*
236	*Senecio ovatus*	*Asteraceae*
237	*Silene dioica*	*Caryophyllaceae*
238	*Soldanella hungarica*	*Primulaceae*
239	*Soldanella hungarica*	*Primulaceae*
240	*Soldanella pusilla*	*Primulaceae*
241	*Solidago virgaurea*	*Asteraceae*
242	*Sorbus aucuparia*	*Rosaceae*
243	*Spiraea chamaedryfolia*	*Rosaceae*
244	*Stachys sylvatica*	*Lamiaceae*
245	*Stellaria alsine*	*Caryophyllaceae*
246	*Stellaria media*	*Caryophyllaceae*
248	*Stellaria nemorum*	*Caryophyllaceae*
249	*Symphytum cordatum*	*Boraginaceae*
250	*Tanacetum vulgare*	*Asteraceae*
251	*Taraxacum officinale agg.*	*Asteraceae*
252	*Telekia speciosa*	*Asteraceae*
253	*Thalictrum aquilegiifolium*	*Ranunculaceae*
254	*Tilia platyphyllos*	*Tiliaceae*
255	*Trifolium pratense*	*Fabaceae*
256	*Trifolium repens*	*Fabaceae*
257	*Tussilago farfara*	*Asteraceae*
258	*Typha latifolia*	*Typhaceae*
259	*Ulmus glabra*	*Ulmaceae*
260	*Ulmus minor*	*Ulmaceae*
261	*Urtica dioica*	*Urticaceae*
262	*Vaccinium myrtillus*	*Ericaceae*
263	*Vaccinium vitis-idaea*	*Ericaceae*
264	*Valeriana tripteris*	*Valerianaceae*
265	*Veratrum album* subsp. *album*	*Liliaceae*
266	*Verbascum nigrum*	*Scrophulariaceae*
267	*Veronica beccabunga*	*Scrophulariaceae*
268	*Veronica chamaedrys*	*Scrophulariaceae*
269	*Veronica officinalis*	*Scrophulariaceae*
270	*Veronica cf. serpyllifolia*	*Scrophulariaceae*
271	*Veronica urticifolia*	*Scrophulariaceae*
272	*Vicia cracca*	*Fabaceae*
273	*Viola canina*	*Violaceae*
274	*Viola declinata*	*Violaceae*
275	*Viola reichenbachiana*	*Violaceae*

Table 4 Preliminary list of birds found in the Boişoara Forest. Annex I species of the Birds Directive are indicated by an asterisk (*)

No.	Species	Forest	Grass-land	No.	Species	Forest	Grass-land
1	*Accipiter nisus*	X		24	*Motacilla alba*	X	X
2	*Alauda arvensis*		X	25	*Motacilla cinerea*	X	
3	*Anthus spinoletta*		X	26	*Nucifraga caryocatactes*	X	
4	*Anthus trivialis*		X	27	*Oenanthe oenanthe*		X
5	*Bonasia bonasia**	X		28	*Parus ater*	X	X
6	*Buteo buteo*	X	X	29	*Parus caeruleus*	X	
7	*Carduelis cannabina*		X	30	*Parus cristatus*	X	
8	*Certhia familiaris*	X		31	*Parus major*	X	
9	*Ciconia nigra**	X	X	32	*Parus montanus*	X	
10	*Cinclus cinclus*	X		33	*Phoenicurus ochruros*		X
11	*Columbia palumbus*	X		34	*Phylloscopus collybita*	X	
12	*Cuculus canorus*	X		35	*Picus viridis*	X	
13	*Dendrocopos leucotos**	X		36	*Prunella collaris*	X	X
14	*Dendrocopos major*	X		37	*Pyrrhula pyrrhula*	X	
15	*Dryocopus martius**	X		38	*Regulus regulus*	X	
16	*Erithacus rubecula*	X	X	39	*Saxicola rubetra*		X
17	*Ficedula albicollis*	X		40	*Stryx aluco*	X	
18	*Ficedula hypoleuca*	X		41	*Sylvia atricapilla*	X	
19	*Ficedula parva*	X		42	*Tertrao urogallus**	X	
20	*Fringilla coelebs*	X	X	43	*Troglodytes troglodytes*	X	
21	*Garrulus glandarius*	X		44	*Turdus merula*	X	
22	*Hirundo rustica*		X	45	*Turdus philomelos*	X	X
23	*Loxia curvirostra*	X	X	46	*Turdus torquatus*		X

Table 5 Preliminary List of the Coleoptera found in the Boişoara Forest (May 5 to 10, 2012)

No.	Taxon	Remark
	Carabidae	
1	*Carabus auronitens* F., 1792	
2	*Carabus coriaceus* L., 1758	
3	*Carabus glabratus* Payk., 1790	Indicator for old growth forest
4	*Carabus intricatus* L., 1761	
5	*Carabus planicollis* Küst., 1846	Carpathian endemite
6	*Tachyta nana* (Gyll., 1810)	Saproxylic species
	Silvidae	
7	*Necrophorus vespillo* (L., 1758)	
	Leiodidae	
8	*Agathidium dentatum* Muls.Rey, 1861	
	Staphylinidae	
9	*Scaphidium quadrimaculatum* Ol., 1790	
10	*Atrecus longiceps* (Fauv., 1872)	
11	*Olisthaerus substriatus* (Payk., 1790)	Urwald relict species (Müller et al. 2005)
12	*Gyrophaena gentilis* Er., 1839	
	Lymexylonidae	
13	*Hylecoetus dermestoides* (L., 1761)	
	Elateridae	
14	*Ctenicera virens* (Schrk., 1781)	
15	*Melanotus rufipes* (Hbst., 1784)	
16	*Ampedus pomorum* (Steph., 1830)	
17	*Actenicerus sjaelandicus* (Müll., 1764)	
	Buprestidae	
18	*Anthaxia helvetica* Stierl., 1868	
	Cerylonidae	
19	*Cerylon ferrugineum* Steph., 1830	
	Cucujidae	
20	*Cucujus cinnaberinus* (Scop., 1763)	Annex II and IV Habitats directive
	Erotylidae	
21	*Triplax rufipes* (F., 1775)	
22	*Dacne rufifrons* (F., 1775)	
	Colydiidae	
23	*Bitoma crenata* (F., 1775)	
	Endomychidae	
24	*Endomychus coccineus* (L., 1758)	
	Ciidae	
25	*Cis nitidus* (F., 1792)	
26	*Ropalodontus perforatus* (Gyll., 1813)	Indicator for habitat continuity (Fomes)
	Anobiidae	
27	*Xestobium austriacum* Rtt., 1890	Urwald relict species (Müller et al. 2005)
	Pyrochroidae	
28	*Schizotus pectinicornis* (L., 1758)	
	Tenebrionidae	
29	*Bolitophagus reticulatus* (L., 1767)	Indicator for habitat continuity (*Fomes*)

Table 5 (continuation)

No.	Taxon	Remark
	Meloidae	
30	*Meloe violaceus* Marsh., 1802	
	Geotrupidae	
31	*Geotrupes stercorarius* (L., 1758)	
32	*Anoplotrupes stercorosus* (Scriba, 1791)	
	Lucanidae	
33	*Platycerus caraboides* (L., 1758)	
34	*Sinodendron cylindricum* (L., 1758)	Indicator for coarse woody debris
	Cerambycidae	
35	*Rhagium mordax* (Degeer, 1775)	
36	*Rhagium inquisitor* (L., 1758)	
37	*Tetropium castaneum* (L., 1758)	
38	*Oxymirus cursor* (L., 1758)	
39	*Evodinus clathratus* (F., 1792)	
40	*Cerambyx scopolii* Fuessl., 1775	
41	*Xylotrechus rusticus* (L., 1758)	
42	*Morimus funereus* Muls., 1863	Annex II Habitats Directive
43	*Mesosa nebulosa* (F., 1781)	
44	*Monochamus spp.*	
45	*Saperda perforata* (Pall., 1773)	
	Chrysomelidae	
46	*Agelastica alni* (L., 1758)	
	Scolytinae	
47	*Scolytus ratzeburgi* Janson, 1856	
48	*Pityogenes chalcographus* (L., 1761)	
49	*Taphrorychus bicolor* (Hbst., 1793)	
50	*Xyloterus lineatus* (Ol., 1795)	
51	*Ips amitinus* (Eichh., 1871)	
	Anthribidae	
52	*Anthribus albinus* (L., 1758)	
	Curculionidae	
53	*Liparus glabrirostris* Küst., 1849	
54	*Otiorhynchus gemmatus* (Scop., 1763)	

Supplementary material

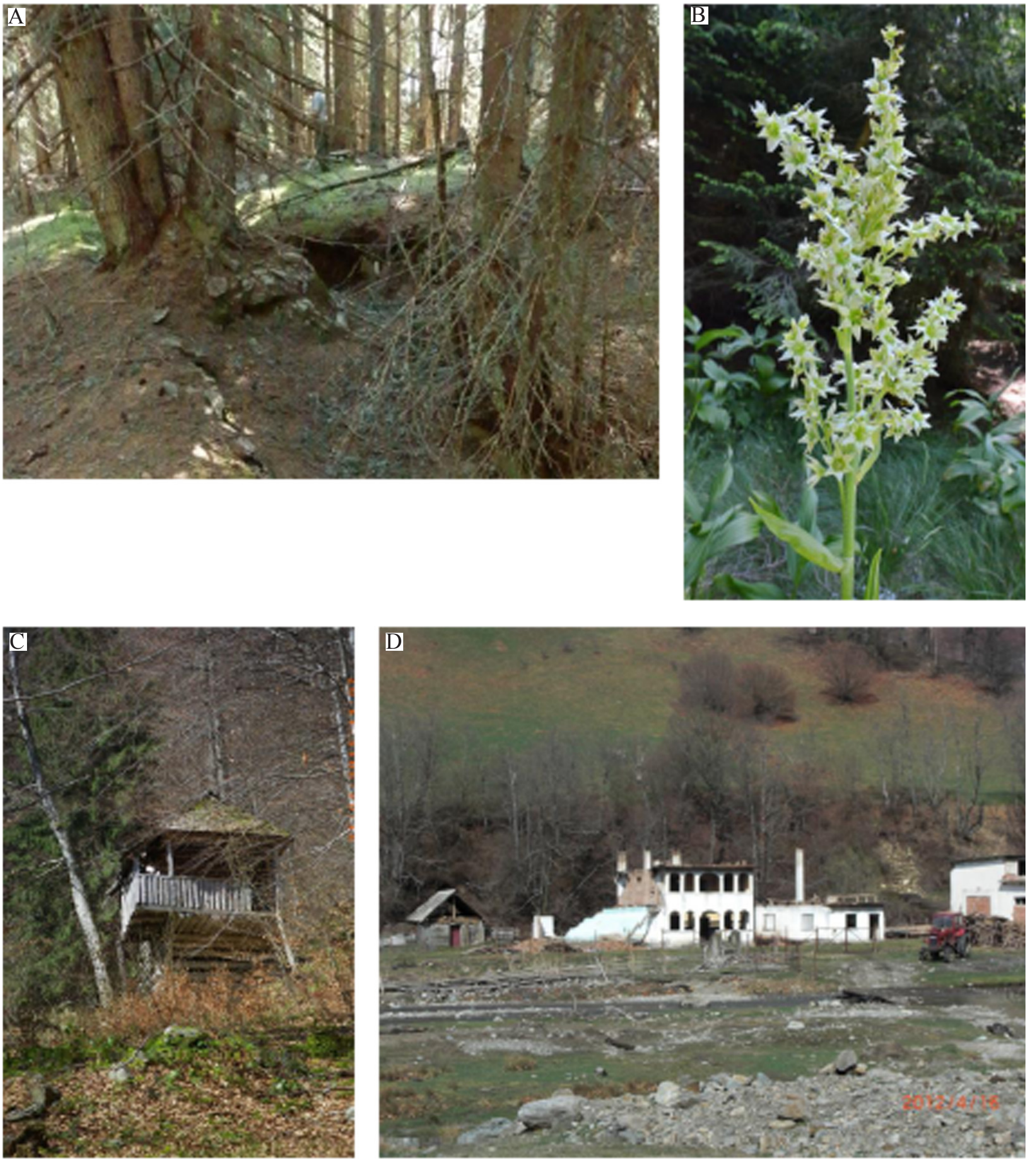


Figure S1 Forest history

Note: A: trenched spruce forests (Photo: A. Heßberg). B: Veratrum album as typical pastureland relict species in a spruce forest (Photos: E.D. Schulze). C-D: Former hide for bear hunting. C: Sitting game, D: Hunting chalet (Photos: E.D. Schulze)

Figure S2 Veteran tree (*Fagus sylvatica* with DBH of 115.5 cm; Photo: A. Heßberg)

Figure S3 Forest management

Note: A: Regeneration cluster of beech without any contribution of rare tree species (Photo: E.D. Schulze). B: The remaining trees are currently often poorly formed, heavily branched or damaged (Photo: E.D. Schulze)