

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

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Abstract. Biodiversity and forest management are analyzed for a 500 ha privately owned forest within the Natura 2000 area “ROSCI0122 Munții Făgăraș”. 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 Făgăraș, 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, Făgăraș, Boișoara.

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.

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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 Boișoara forest, that is owned and managed by the Boișoara Forest Enterprise. The forest is located in the Făgăraș Mountains, that are in the southern bow of the Carpathian Mountains, Boișoara 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 Boișoara forest is part of the Natura 2000 area of the Romanian Site of Community Importance, “ROSCI0122: Munții Făgăraș“. The area of ROSCI Munții Făgăraș 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 Făgăraș Mountains belong



Figure 1 Geographic map of the study area: Southern Carpathian Mountains (up right) and Boisoara 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 (°C)	Annual rainfall (mm)
pediment							
lower	colline	Euro-Siberian steppic woods with <i>Quercus spp.</i>	9110 ^x	<i>Quercus, Acer, Tilia, Sorbus</i>	200-500	>9-10.5	< 650
median	colline to submontane	Dacian oak-hombeam forests	91YO	<i>Carpinus, Quercus, Tilia,</i>	500-700	8-9	650-800
upper	submontane	warmbeech forests	91VO	<i>Fagus, Carpinus</i>	700-900	7-8	
montane							
lower	lower montane	cool beech forests		<i>Fagus</i>	900-1100	6-7	
median	midmontane	mixed mountain forests	91V0, 9110	<i>Fagus, Abies, Picea</i>	1100-1300	5-6	800-1100
upper	upper montane	mixed mountain forests		<i>Picea, Abies, Fagus</i>	1300-1500	4-5	
subalpine							
lower	lower subalpine	spruce forests	9410	<i>Picea</i>	1500-1800	2.5-4	1100-1200
upper	upper subalpine	krummholz	4060, 4070	<i>Pinus mugo</i>	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 refugia and as a link between different biogeographic regions. The flora and fauna of the Boișoara 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 Făgăraș Mountains district (Borza & Boșcaiu 1965).

The Făgăraș 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 Făgăraș.

ROSCI Munții Făgăraș 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 Făgăraș

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

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 Boișoara at Mt. Caligaru (1715 m a.s.l.) is about 100 m below the timberline in the Făgăraș Mountains. At the treeline, the mean annual temperature is estimated to be $+2^{\circ}\text{C}$ 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.

Boișoara Forest extends across the historic border between the Austro-Hungarian Monar-

chy (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 Ceaușescu 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 Union 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. Ceaușescu until December 1989. Ceaușescu reserved large forest districts as personal hunting grounds. On the east side of Boișoara forest old hides for bear hunting and the ruins of a large villa are evidence that this old growth forest was part of a Ceaușescu hunting range (Figure 1C-D, Suppl. material). The present borders of the Romanian hunting districts still follow the partitioning introduced by Ceaușescu, and contain huge areas per district (>10,000 ha) which are difficult to control operatively and administratively.

Boișoara forest belonged to the Popovich family, who have lived in Curtea de Argeș, 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 Argeș 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). Boișoara forest was sold by Necula to Boișoara 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 Boișoara 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 Ceaușescu 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.

Boișoara 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 Boișoara 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

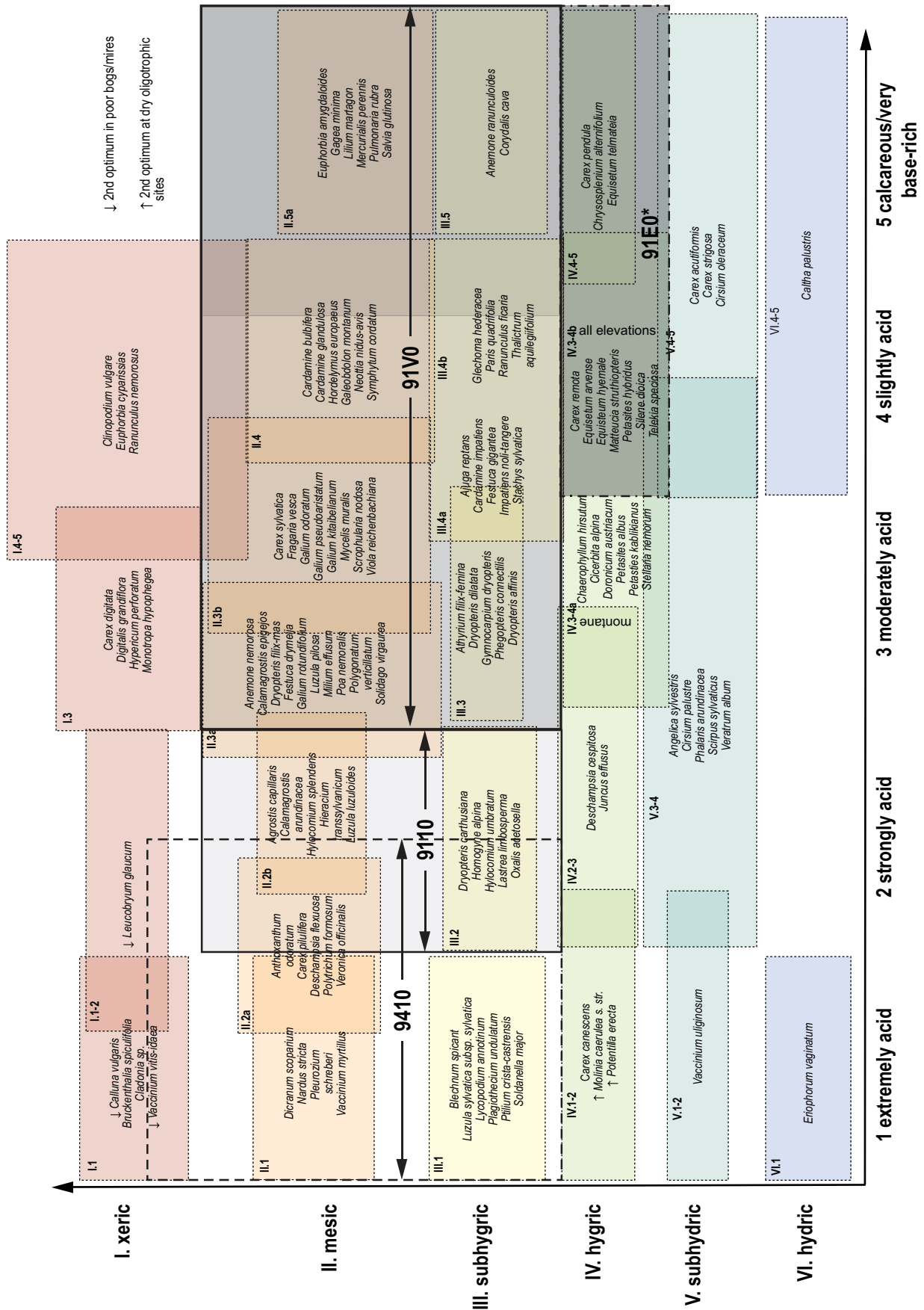
The main plant communities, as summarized in relation to soil acidity and water supply (Figure 2) extend across a very wide range of soil acidity, water status and elevation.

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 Boișoara 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	(<i>Soldanelleno majoris-Piceetum</i>)
9110 Luzulo-Fagetum beech forests	(<i>Hieracio rotundati-Fagetum</i>)
91V0 Dacian beech forests	(<i>Dentario glandulosae-Fagetum</i>)
91V0 Dacian beech forests	(<i>Pulmonario rubrae-Fagetum</i>)
91E0* Alluvial forests with <i>Alnus glutinosa</i> and <i>Fraxinus excelsior</i>	(<i>Telekio speciosae-Alnetum incanae</i>)



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; *Viola 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 kablíkianum* 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 Boișoara 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

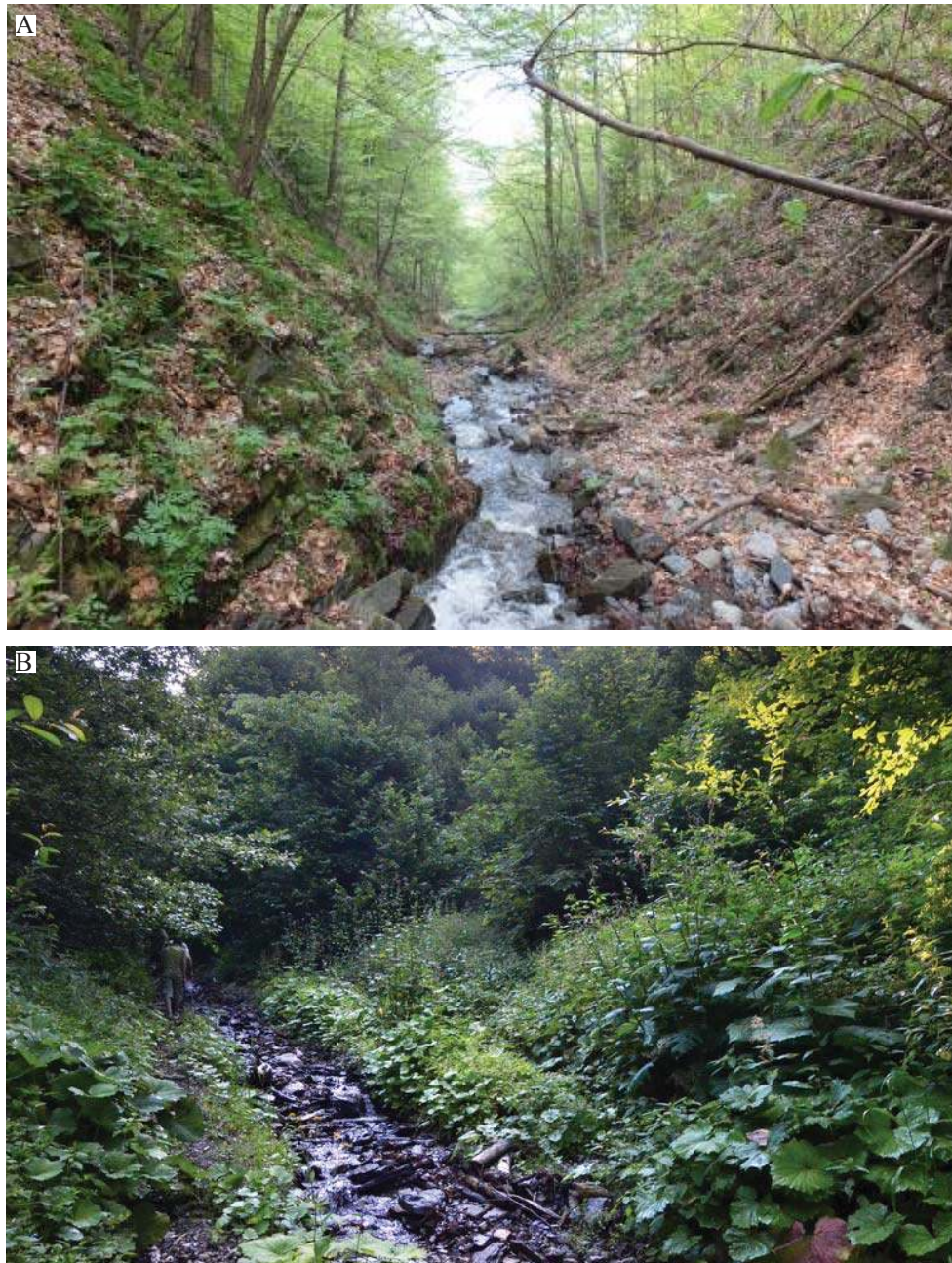


Figure 4 Mountain valleys

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 Boișoara forest. Admixed individuals of *Fagus* and *Abies* indicate that a mixed mountain forest might be more natural.

Most *Fagus* and *Picea* stands in Boișoara 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 (re-foresting 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 (Figure 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 individual 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 latifolia* 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 cinnaberinus* (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*, *Hy-*

pogymnia 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	<i>Fagus</i> forest	Mixed alpine forest	<i>Picea</i> 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 $>30 \text{ m}^3 \text{ ha}^{-1}$, which is important in cool forests (La-

chat 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 $>35^\circ$, 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 “ameajament” 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 Boișoara forest. The site was above 1500 m elevation. The grid was comprised of 45 circles of 1000 m², 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 Boiçoara forest based on 45 inventory plots of 1000m² per plot

DBH (cm)	Density (trees per ha)	Basal area (m ² ha ⁻¹)	Wood volume (m ³ ha ⁻¹)	Option 1		Option 2		Option 3	
				Thinning from top		Thinning from below		Thinning balance	
				Remain- ing density (trees ha ⁻¹)	Remain- ing volume (m ³ ha ⁻¹)	Remain- ing density (trees ha ⁻¹)	Remain- ing volume (m ³ ha ⁻¹)	Remain- ing density (trees ha ⁻¹)	Remain- ing 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	
20-30	315	15.2	102.1	31	4	99	32	99	8
30-40	150	13.1	98.6	15	10	32	21	32	32
40-50	57	8.9	62.1	56	10	8	9	27	21
50-60	15	3.7	23.2	15	62	5	7	10	30
60-70	3	0.9	5.2	3	23	5	5	5	15
70-80	1	0.2	1.2	1		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 45° 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 m² ha⁻¹, and a wood volume of about 340 m³ 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 m³ 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 m³ 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 m³ 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 m³ 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 tractors 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 Ceaușescu 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.

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Appendix

Table 1 Habitat Classes of the ROSCI0122 Munții Făgăraș

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, Scree, 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 Făgăraș

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 <i>Nardus</i> grasslands, on siliceous substrates in mountain areas	0.1	A	A	A	A
91E0* - Alluvial forests with <i>Alnus glutinosa</i> and <i>Fraxinus excelsior</i> (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 criteria (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 Boișoara Forest

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

Table 3 (continuation)

No.	Plant species	Family	No.	Plant species	Family
45	<i>Carduus acanthoides</i>	Asteraceae	107	<i>Euphorbia amygdaloides</i>	Euphorbiaceae
46	<i>Carduus personata</i>	Asteraceae	108	<i>Euphorbia cyparissias</i>	Euphorbiaceae
47	<i>Carex canescens</i>	Cyperaceae	109	<i>Fagus sylvatica</i>	Fagaceae
48	<i>Carex caryophyllea</i>	Cyperaceae	110	<i>Festuca drymeja</i>	Poaceae
49	<i>Carex cf strigosa</i>	Cyperaceae	111	<i>Festuca gigantea</i>	Poaceae
50	<i>Carex digitata</i>	Cyperaceae	112	<i>Festuca rubra</i>	Poaceae
51	<i>Carex ligerica</i>	Cyperaceae	113	<i>Fragaria vesca</i>	Rosaceae
52	<i>Carex pendula</i>	Cyperaceae	114	<i>Fraxinus excelsior</i>	Oleaceae
53	<i>Carex pilulifera</i>	Cyperaceae	115	<i>Gagea minima</i>	Liliaceae
54	<i>Carex remota</i>	Cyperaceae	116	<i>Galeobdolon montanum</i>	Lamiaceae
55	<i>Carex sylvatica</i>	Cyperaceae	117	<i>Galanthus nivalis</i>	Amaranthaceae
56	<i>Carlina acaulis</i>	Asteraceae	118	<i>Galeopsis tetrahit</i>	Lamiaceae
57	<i>Carpinus betulus</i>	Betulaceae	119	<i>Galium kitaibelianum</i>	Rubiaceae
58	<i>Centaurea jacea</i>	Asteraceae	120	<i>Galium odoratum</i>	Rubiaceae
59	<i>Cephalaria pilosa</i>	Caprifoliaceae	121	<i>Galium palustre</i>	Rubiaceae
60	<i>Cerastium fontanum</i>	Caryophyllaceae	122	<i>Galium pseudoaristatum</i>	Rubiaceae
61	<i>Chaerophyllum bulbosum</i>	Apiaceae	123	<i>Gentiana asclepiadea</i>	Gentianaceae
62	<i>Chaerophyllum hirsutum</i>	Apiaceae	124	<i>Gentiana acaulis</i>	Gentianaceae
63	<i>Chaerophyllum temulum</i>	Apiaceae	125	<i>Gentiana pneumonanthe</i>	Gentianaceae
64	<i>Chelidonium majus</i>	Papaveraceae	126	<i>Geranium pyrenaicum</i>	Geraniaceae
65	<i>Chenopodium album</i>	Amaranthaceae	127	<i>Geranium robertianum</i>	Geraniaceae
66	<i>Chenopodium bonus-henricus</i>	Amaranthaceae	128	<i>Geum montanum</i>	Rosaceae
67	<i>Chrysosplenium alternifolium</i>	Saxifragaceae	129	<i>Geum urbanum</i>	Rosaceae
68	<i>Cicerbita alpina</i>	Asteraceae	130	<i>Glechoma hederacea</i>	Lamiaceae
69	<i>Cirsium arvense</i>	Asteraceae	131	<i>Glechoma hirsuta</i>	Lamiaceae
70	<i>Cirsium erisithales</i>	Asteraceae	132	<i>Glyceria fluitans</i>	Poaceae
71	<i>Cirsium oleraceum</i>	Asteraceae	133	<i>Gnaphalium sylvaticum</i>	Asteraceae
72	<i>Cirsium palustre</i>	Asteraceae	134	<i>Gymnocarpium dryopteris</i>	Athyriaceae
73	<i>Clinopodium vulgare</i>	Lamiaceae	135	<i>Heracleum sphondylium</i>	Apiaceae
74	<i>Corallorrhiza trifida</i>	Orchidaceae	136	<i>Hieracium transsylvanicum</i>	Asteraceae
75	<i>Cornus sanguinea</i>	Cornaceae	137	<i>Holcus lanatus</i>	Poaceae
76	<i>Corydalis solida</i>	Fumariaceae	138	<i>Homogyne alpina</i>	Asteraceae
77	<i>Corylus avellana</i>	Corylaceae	139	<i>Hordelymus europaeus</i>	Poaceae
78	<i>Crocus vernus</i>	Iridaceae	140	<i>Hypericum hirsutum</i>	Hypericaceae
79	<i>Cruciata glabra</i>	Rubiaceae	141	<i>Hypericum perforatum</i>	Hypericaceae
80	<i>Cruciata laevipes</i>	Rubiaceae	142	<i>Hypericum tetrapterum</i>	Hypericaceae
81	<i>Cynoglossum officinale</i>	Boraginaceae	143	<i>Hypochaeris radicata</i>	Asteraceae
82	<i>Cystopteris fragilis</i>	Athyriaceae	144	<i>Impatiens noli-tangere</i>	Balsaminaceae
83	<i>Dactylis glomerata</i>	Poaceae	145	<i>Juncus alpinoarticulatus</i>	Juncaceae
84	<i>Daucus carota</i>	Apiaceae	146	<i>Juncus articulatus</i>	Juncaceae
85	<i>Dentaria bulbifera</i>	Brassicaceae	147	<i>Juncus effusus</i>	Juncaceae
86	<i>Dentaria glandulosa</i>	Brassicaceae	148	<i>Juncus tenuis</i>	Juncaceae
87	<i>Deschampsia cespitosa</i>	Poaceae	149	<i>Juniperus sibirica</i>	Cupressaceae
88	<i>Deschampsia flexuosa</i>	Poaceae	150	<i>Lamium album</i>	Lamiaceae
89	<i>Digitalis grandiflora</i>	Scrophulariaceae	151	<i>Lamium maculatum</i>	Lamiaceae
90	<i>Doronicum austriacum</i>	Asteraceae	152	<i>Lapsana communis</i>	Asteraceae
91	<i>Dryopteris affinis</i>	Athyriaceae	153	<i>Lastrea limbosperma</i>	Polypodiaceae
92	<i>Dryopteris carthusiana</i>	Athyriaceae	154	<i>Lathraea squamaria</i>	Scrophulariaceae
93	<i>Dryopteris dilatata</i>	Athyriaceae	155	<i>Lathyrus pratensis</i>	Fabaceae
94	<i>Dryopteris filix-mas</i>	Athyriaceae	156	<i>Lathyrus tuberosus</i>	Fabaceae
95	<i>Eleocharis palustris</i>	Cyperaceae	157	<i>Lilium martagon</i>	Liliaceae
96	<i>Elymus repens</i>	Poaceae	158	<i>Lolium perenne</i>	Poaceae
97	<i>Epilobium angustifolium</i>	Onagraceae	159	<i>Lunaria rediviva</i>	Brassicaceae
97	<i>Epilobium parviflorum</i>	Onagraceae	160	<i>Luzula luzuloides</i>	Juncaceae
98	<i>Epilobium roseum</i>	Onagraceae	161	<i>Luzula pilosa</i>	Juncaceae
99	<i>Equisetum arvense</i>	Equisetaceae	162	<i>Luzula sylvatica</i>	Juncaceae
100	<i>Equisetum hyemale</i>	Equisetaceae	163	<i>Lychnis spec.</i>	Caryophyllaceae
101	<i>Equisetum palustre</i>	Equisetaceae	164	<i>Lycopodium annotinum</i>	Lycopodiaceae
102	<i>Equisetum telmateia</i>	Equisetaceae	165	<i>Lysimachia nummularia</i>	Primulaceae
103	<i>Erigeron annuus</i>	Asteraceae	166	<i>Malus spec.</i>	Rosaceae
104	<i>Eriophorum vaginatum</i>	Cyperaceae	167	<i>Matteuccia struthiopteris</i>	Athyriaceae
105	<i>Euonymus latifolia</i>	Celastraceae	168	<i>Medicago lupulina</i>	Fabaceae
106	<i>Eupatorium cannabinum</i>	Asteraceae	169	<i>Mentha longifolia</i>	Lamiaceae

Table 3 (continuation)

No.	Plant species	Family	No.	Plant species	Family
170	<i>Mercurialis perennis</i>	Euphorbiaceae	222	<i>Sagina procumbens</i>	Caryophyllaceae
171	<i>Milium effusum</i>	Poaceae	223	<i>Salicornia fragilis</i>	Caryophyllaceae
172	<i>Moehringia trinervia</i>	Caryophyllaceae	224	<i>Salix caprea</i>	Salicaceae
173	<i>Monotropa hypophegea</i>	Pyrolaceae	225	<i>Salix cinerea</i>	Salicaceae
174	<i>Mycelis muralis</i>	Asteraceae	226	<i>Salix silesiaca</i>	Salicaceae
175	<i>Myosotis arvensis</i>	Boraginaceae	227	<i>Salix triandra</i>	Salicaceae
176	<i>Myosotis scorpioides</i>	Boraginaceae	228	<i>Salvia glutinosa</i>	Lamiaceae
177	<i>Myosoton aquaticum</i>	Caryophyllaceae	229	<i>Sambucus ebulus</i>	Caprifoliaceae
178	<i>Nardus stricta</i>	Poaceae	230	<i>Sambucus nigra</i>	Caprifoliaceae
179	<i>Neottia nidus-avis</i>	Orchidaceae	231	<i>Sambucus racemosa</i>	Caprifoliaceae
180	<i>Oxalis acetosella</i>	Oxalidaceae	232	<i>Saxifraga stellaris</i>	Saxifragaceae
181	<i>Paris quadrifolia</i>	Liliaceae	233	<i>Scilla bifolia</i> subsp. <i>drunensis</i>	Asparagaceae
182	<i>Petasites albus</i>	Asteraceae	234	<i>Scirpus sylvaticus</i>	Cyperaceae
183	<i>Petasites hybridus</i>	Asteraceae	235	<i>Scrophularia nodosa</i>	Scrophulariaceae
184	<i>Petasites kablikianus</i>	Asteraceae	236	<i>Senecio ovatus</i>	Asteraceae
185	<i>Phacelia tancetifolia</i>	Boraginaceae	237	<i>Silene dioica</i>	Caryophyllaceae
186	<i>Phalaris arundinacea</i>	Poaceae	238	<i>Soldanella hungarica</i>	Primulaceae
187	<i>Phegopteris connectilis</i>	Polypodiaceae	239	<i>Soldanella hungarica</i>	Primulaceae
188	<i>Picea abies</i>	Pinaceae	240	<i>Soldanella pusilla</i>	Primulaceae
189	<i>Pinguicula vulgaris</i>	Lentibulariaceae	241	<i>Solidago virgaurea</i>	Asteraceae
190	<i>Plantago lanceolata</i>	Plantaginaceae	242	<i>Sorbus aucuparia</i>	Rosaceae
191	<i>Plantago major</i>	Plantaginaceae	243	<i>Spiraea chamaedryfolia</i>	Rosaceae
192	<i>Platanthera bifolia</i>	Orchidaceae	244	<i>Stachys sylvatica</i>	Lamiaceae
193	<i>Poa humilis</i>	Poaceae	245	<i>Stellaria alsine</i>	Caryophyllaceae
194	<i>Poa nemoralis</i>	Poaceae	246	<i>Stellaria media</i>	Caryophyllaceae
195	<i>Poa pratensis</i>	Poaceae	248	<i>Stellaria nemorum</i>	Caryophyllaceae
196	<i>Poa supina</i>	Poaceae	249	<i>Symphytum cordatum</i>	Boraginaceae
197	<i>Poa trivialis</i>	Poaceae	250	<i>Tanacetum vulgare</i>	Asteraceae
198	<i>Polygala vulgaris</i>	Polygalaceae	251	<i>Taraxacum officinale</i> agg.	Asteraceae
199	<i>Polygonatum verticillatum</i>	Liliaceae	252	<i>Telekia speciosa</i>	Asteraceae
200	<i>Polypodium vulgare</i>	Polypodiaceae	253	<i>Thalictrum aquilegifolium</i>	Ranunculaceae
201	<i>Polystichum aculeatum</i>	Athyriaceae	254	<i>Tilia platyphyllos</i>	Tiliaceae
202	<i>Polystichum braunii</i>	Athyriaceae	255	<i>Trifolium pratense</i>	Fabaceae
203	<i>Populus tremula</i>	Salicaceae	256	<i>Trifolium repens</i>	Fabaceae
204	<i>Potentilla argentea</i>	Rosaceae	257	<i>Tussilago farfara</i>	Asteraceae
205	<i>Potentilla erecta</i>	Rosaceae	258	<i>Typha latifolia</i>	Typhaceae
206	<i>Potentilla ternata</i>	Rosaceae	259	<i>Ulmus glabra</i>	Ulmaceae
207	<i>Primula spec.</i>	Primulaceae	260	<i>Ulmus minor</i>	Ulmaceae
208	<i>Prunella vulgaris</i>	Lamiaceae	261	<i>Urtica dioica</i>	Urticaceae
209	<i>Prunus avium</i>	Rosaceae	262	<i>Vaccinium myrtillus</i>	Ericaceae
210	<i>Pulmonaria rubra</i>	Boraginaceae	263	<i>Vaccinium vitis-idaea</i>	Ericaceae
211	<i>Pyrus communis</i>	Rosaceae	264	<i>Valeriana tripteris</i>	Valerianaceae
212	<i>Ranunculus acris</i>	Ranunculaceae	265	<i>Veratrum album</i> subsp. <i>album</i>	Liliaceae
213	<i>Ranunculus cf. montanus</i>	Ranunculaceae	266	<i>Verbascum nigrum</i>	Scrophulariaceae
214	<i>Ranunculus cf. nemorosus</i>	Ranunculaceae	267	<i>Veronica beccabunga</i>	Scrophulariaceae
215	<i>Ranunculus repens</i>	Ranunculaceae	268	<i>Veronica chamaedrys</i>	Scrophulariaceae
216	<i>Rhamnus cathartica</i>	Rhamnaceae	269	<i>Veronica officinalis</i>	Scrophulariaceae
217	<i>Rosa spec.</i>	Rosaceae	270	<i>Veronica cf. serpyllifolia</i>	Scrophulariaceae
218	<i>Rubus fruticosus</i> agg.	Rosaceae	271	<i>Veronica urticifolia</i>	Scrophulariaceae
219	<i>Rubus idaeus</i>	Rosaceae	272	<i>Vicia cracca</i>	Fabaceae
220	<i>Rumex acetosa</i>	Polygonaceae	273	<i>Viola canina</i>	Violaceae
221	<i>Rumex obtusifolius</i>	Polygonaceae	274	<i>Viola declinata</i>	Violaceae
			275	<i>Viola reichenbachiana</i>	Violaceae

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

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

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

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

Table 5 (continuation)

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