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Romania's natural forest types – a biogeographic and phytosociological overview in the context of politics and conservation

Die natürlichen Waldtypen Rumäniens – eine biogeographische und vegetationskundliche Übersicht im Kontext von Politik und Naturschutz

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Abstract

This report provides an overview of the forest vegetation and the status of its conservation in Romania. Due to a large range of climates and soils, and a long-lasting postglacial vegetation history, the Romanian forests are highly diverse and species-rich ecosystems. Approximately 150 natural types of forest ecosystems have been described. Seven zonal forest formations were distinguished: (1) forest steppes and dry oak forests; (2) forests with Oriental hornbeam (*Carpinus orientalis*); (3) forests with oaks (*Quercus* spp.) and hornbeam (*Carpinus betulus*); (4) beech forests: *Fagus sylvatica* and *Fagus sylvatica* mixed forests; (5) beech-fir (*Abies alba*)-spruce (*Picea abies*) mixed mountain forests; (6) spruce forests; (7) subalpine shrubland with dwarf pine (*Pinus mugo* subsp. *mugo*). On extreme sites, azonal forests occur, dominated by (8) black pine (*Pinus nigra* subsp. *banatica*); (9) Scots pine (*Pinus sylvestris*); (10) Carpathian larch (*Larix decidua* subsp. *carpatica*) and stone pine (*Pinus cembra*); (11) valuable broadleaf species, including maple (*Acer* spp.), ash (*Fraxinus* spp.), elm (*Ulmus* spp.), linden (*Tilia* spec). Along water courses with periodical inundations, riparian forests and shrublands occur, dominated by (12) black alder (*Alnus glutinosa*); (13) grey alder (*A. incana*); (14) tamarisk (*Myricaria germanica*) pioneer copse; (15) pioneer forest with poplar (*Populus* spp.) and willow (*Salix* spp.); (16) riparian hardwood forest with oak, elm (*Ulmus* spp.), ash (*Fraxinus* spp.).

In the EU countries virgin (primeval) and old growth forests account for less than 3% of the total forest area. Most alarming is the situation of temperate virgin and old-growth forest. About 80% of them are situated in the Carpathians, mainly formed by beech, fir, and spruce. Estimations of virgin and quasi-virgin, old-growth forests in Romania range between 150,000 and 200,000 ha. Between 2001 and 2019 about 350,000 ha disappeared through illegal and legal logging. Legislation in Romania demands that production forests have to be managed sustainably, and virgin forests have to be protected. Romanian forests are also subject to European law, such as the Habitats and Birds Directives. However, there is a severe lack of enforcement at all administration levels, even in National Parks. Sanctioning

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activities by the EU authorities are hardly visible. It follows: (1) It must be in the interest of all of Europe to preserve and protect the last large areas of primeval forest in Europe. (2) The community of EU countries, the Parliament and the European Commission must provide clear guidelines and care for their implementation, connected with attractive, secure and long-term funding programs (compensation for non-use). (3) At a regional level, new creative ideas and concrete initiatives must integrate wilderness areas into regional value creation concepts.

Keywords: altitudinal zonation, Carpathians, temperate forest, virgin forest, zonal and azonal vegetation

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Without anthropogenic influences, tree-dominated ecosystems would cover between 70 and 80% of Romania's land area (GIURESCU 1975, BIRIŞ 2017). Only the alpine zone of the Carpathians, the secondary steppes of western Transylvania, and eastern Wallachia, southern Moldavia and Dobrudja, excessively flooded areas along large rivers and in the delta of Danube, and permanently wet swamps and bogs would be unforested.

The most common tree species are European beech (*Fagus sylvatica*) (32%), Norway spruce (*Picea abies*) (20%), silver fir (*Abies alba*) (19%) and oak species (*Quercus* spp.) (17%) (IFN 2020). Large areas of the lowlands and the colline zone are unforested; their natural forests were destroyed in prehistorical and historical times and converted into pasturage and agricultural landscapes, like in entire Central Europe. In the colline lowlands, oak-hornbeam (*Carpinus betulus*) and beech forests remain only locally and mainly on northern slopes. Similar patterns are more common in the side valleys of the Târnava Mare and in the Southern Carpathian Mountain range and Apuseni Mountains.

Due to a large range of climates and soils, and a long-lasting postglacial vegetation history, the Romanian forests are highly diverse and species-rich (Supplement S1). For example, Romania is a centre of taxonomic and genetic diversity for deciduous *Quercus* species, and speciation is still ongoing (cf. NEOPHYTOU 2014). Due to the altitude above sea level and associated climatic factors, all elevation zones occur here: from lowland, colline (foothills), submontane and montane (mountainous zone) to subalpine and alpine zones (above the tree line). The different macroclimate (continental cold winters in intramontane basins, particularly in the Eastern Carpathians; moderate to sub-Mediterranean climate in the Southwest) characterises the geographical extent of these altitudes and their (forest) vegetation. Local climate factors such as Foehn effects in leeward mountain sites or frequent late frost in plateaus and depressions create further climatic differentiation. The influences of geology and soil also play a role.

Large continuous forests are still found in the Carpathian Arc as the last remaining extensive, coherent natural forests in Europe's temperate climate, in places with a wilderness character and virgin (primeval) and near-natural old-growth which in Romanian are called "quasi-virgin" forests. Very regionalised or localised extra-zonal and azonal forests with their specialised flora (and fauna) are highly significant from an ecological, cultural and scientific perspective. They are often located at the periphery of the species range and are particularly vital for preserving the gene pool and evolutionary development of many species. In the following we (1) present and characterise natural forest and shrubland types and their principal tree species and (2) give a status report on the situation and threats of Romanian virgin and old-growth forests.

2. Romania's natural forest types – a biogeographic and phytosociological overview

Reflecting the diversity of climate, soils and geobotanical-floristic provinces Romania has many different flora and fauna elements and habitats. The macroclimate divides the country's habitats including forests into a Pontic region and a Central European region (HORVAT et al. 1974, MEUSEL et al. 1965, 1992). The Pontic lowlands with their warm, dry continental climate include the "Danubian" lowland and the "Thracian" Plateau of Dobrudja in South-east Romania. Transitional to the Central European region are the "Pannonian" plain (from Hungary to Western Romania) and the "Transylvanian Basin", which was filled with tertiary sediments during the buckling that led to the formation of the Carpathian Mountains and became an upland. The mountain ranges (Eastern and Southern Carpathians, Apuseni Mountains) and the "Illyrian" uplands in Banat (Southwest Romania) are characterised by a temperate climate. Some of these regions overlap with geobotanical-floristic provinces (BORZA 1965 in BORZA & BOŞCAIU 1965): (1) The European East Carpathian province, (2) the Dacian-Illyrian province, (3) the Balkan-Moesia province, (4) the Pontic-Sarmatia province, (5) the Euxinian province and (6) the floodplain of the Danube and its delta. A corresponding classification (KNORN et al. 2012) defines ten ecozones (Fig. 1). They are related with the diversity of tree species and their distribution types (names of plant species after EURO+MED 2006-):

- Submediterranean and oromediterranean species: *Carpinus orientalis*, *Fraxinus ornus*, *F. angustifolia* subsp. *oxycarpa*, *F. pallisae*, *Pinus nigra* subsp. *banatica*, *Quercus pubescens* s.l. incl. *Q. virgiliana*, *Q. cerris*, *Sorbus domestica*, *S. torminalis*, *Celtis australis*, *Jasminum fruticans* and *Staphylea pinnata*.
- Pontic species: *Acer tataricum*, *Quercus pedunculiflora* (= *Q. robur* subsp. *pedunculiflora*), *Fagus* × *taurica*, *Fraxinus excelsior* subsp. *coriariifolia* (rare and very local distribution in Eastern Romania and the Macin mountains/Dobrudja), *Celtis glabrata* (Macin mountains, on rocky habitats). Unclear oak taxa are *Quercus polycarpa* and *Q. dalechampii*, both at least related to *Q. petraea*.
- Species of the Central Balkans: *Quercus frainetto*, *Tilia tomentosa*, *Corylus colurna*, *Cotinus coggygria*.
- Central European species: *Fagus sylvatica*, *Abies alba*, *Quercus petraea*, *Q. robur*, *Tilia cordata*, *T. platyphyllos*, *Acer pseudoplatanus*, *A. platanoides*, *Carpinus betulus*, *Prunus avium* and *Taxus baccata*.
- Nordic-continental species: *Picea abies*, *Larix decidua* subsp. *carpatica*, *Pinus sylvestris*, *P. cembra*, *P. mugo* subsp. *mugo* and *Betula carpatica*.

The forest vegetation of Romania is highly diverse and floristically extremely rich. DONIȚĂ et al. (1990) differentiated approximately 150 forest types. More recently, COLDEA et al. (2015) described 74 forest and 22 shrubland communities. The climatic, edaphic and species diversity has created specific forest habitats in Romania, many of which also have Europe-wide significance as NATURA 2000 habitat types (under the EU Habitats Directive) (inter alia HORVAT et al. 1974, DONIȚĂ et al. 2005, 2008, GAFTA & MOUNTFORD 2008). In this overview we distinguish 7 zonal forest and shrubland formations, mainly along the altitudinal gradient from forest steppe to subalpine shrubland (Supplement E1), belonging to 9 ecozones sensu KNORN et al. (2012; Fig. 1). Additionally, on azonal, extreme sites, nine specialised forest types occur (Supplement S1).

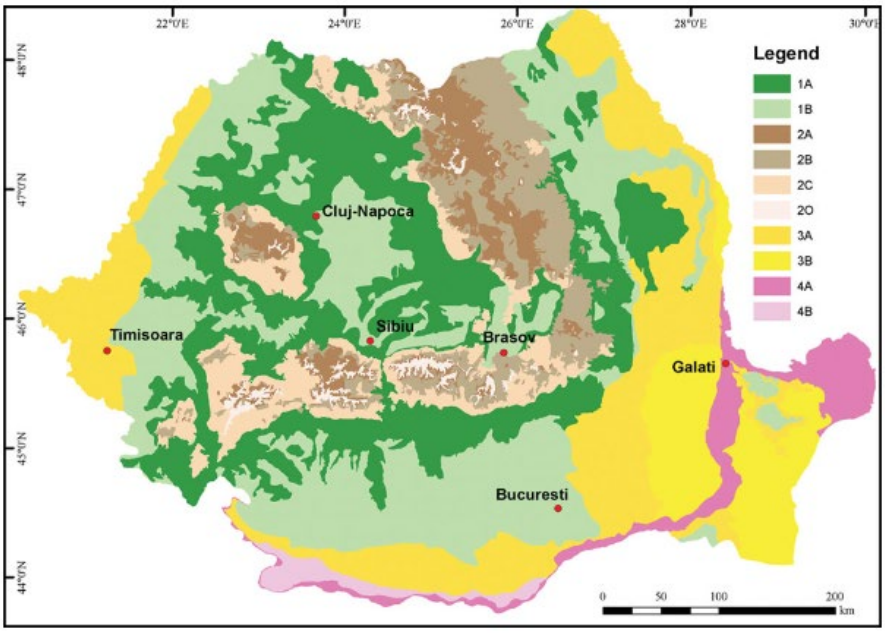

Fig. 1. Romania's potential natural forest-ecozones of Romania (KNORN et al. 2012): 1A = beech and sessile oak mixed forests, Hungarian oak (*Quercus frainetto*) and mixtures, on high and medium hills; 1B = forests with pedunculate oak (*Q. robur*), Turkey oak (*Q. cerris*), Hungarian oak and other species, on low hills and plains; 2A = spruce (*Picea abies*) forests; 2B = coniferous and beech (*Fagus sylvatica*) mixed forests; 2C = beech mountainous forests; 2O = alpine grasslands and/or bare rocks; 3A = xerophyte oak forests in forest steppe; 3B = steppe (no natural forest vegetation); 4A = floodplain forests with poplar (*Populus* spp.), willow (*Salix* spp.), alder (*Alnus glutinosa*) and some pedunculate oak; and 4B = high floodplain forests with pedunculate oak and ash (*Fraxinus excelsior*).

Abb. 1. Potentiell-natürliche Waldzonen Rumäniens (KNORN et al. 2012): 1A = Buchen- und Trauben-Eichen-Mischwälder, Ungarische Eiche (*Quercus frainetto*) und ihre Mischwälder, im höheren Hügelland; 1B = Wälder mit Stiel-Eiche (*Q. robur*), Zerr-Eiche (*Q. cerris*), Ungarischer Eiche und wieteren Arten, im tieferen Hügelland und Ebenen; 2A = Fichtenwälder; 2B = Nadelwälder und Mischwälder mit Buche; 2C = Montane Buchenwälder; 2O = alpine Rasen und/oder Felsen; 3A = Eichenwälder der Waldsteppe; 3B = Steppe (natürlich waldfrei); 4A = Weichholz-Auenwälder mit Pappeln (*Populus* spp.), Weiden (*Salix* spp.), Erlen (*Alnus glutinosa*) und wenigen Stieleichen; 4B= Hartholz-Auenwälder mit Stiel-Eichen und Eschen (*Fraxinus excelsior*).

2.1 Zonal forests

2.1.1 Forest steppes and dry oak forests

In the Romanian lowlands, with pronounced summer droughts and cold winters, the north-poüntic steppes peter out towards the West. In the Southeast of Romania (Dobrudja, Wallachia), there is a transition from steppe, to "forest steppe", to oak and mixed oak forests (NIEDERMEIER 1983, DONIȚĂ et al. 2008) (Fig. 2a).

As the water supply improves the "forest steppe" transitions into deciduous oak and mixed oak forests. Especially on base-rich soils, oak-dominant forest stands mixed with *Sorbus torminalis*, *S. domestica*, *Pyrus communis* and *Malus sylvestris* support a rich diversity of species.

We distinguish the following types of oak forests:

- The low, open tree layer (6 to 10 m in height) marks the transition from **forest steppe** to the pannonic and pontic steppe (DONIȚĂ 1970, BOHN et al. 2002/2003, SCHNEIDER-BINDER 2013). The northern part of the Transylvanian highlands as far as Mureș river, the so-called "Câmpia Transilvaniei" ("Mezőség"), is classified as forest steppe (PAȘCOVSCHI & DONIȚĂ 1967, NIEDERMAIER 1983).
- In the lower Danubian plain with its continental climate and hot summers, species-rich *Quercus* **forests with *Quercus pedunculiflora*** form the zonal xerothermal forests. Stands of loess substrate in the south and southeast of Romania are *Q. pedunculiflora* forests mixed with *Acer tataricum*, *Sorbus torminalis* and *Fraxinus ornus* (COLDEA & POP 1996, OPREA 2004, DONIȚĂ et al. 2008, COLDEA et al. 2015).
- **Forests with *Quercus pubescens*** colonise local calcareous or marly rendzinas. They are found in the Transylvanian Basin at altitudes of 250 to 450 m a.s.l., in the Danubian plain, in the South of Moldova and in the Dobrudja region (JAKUCZ 1961, ȘTEFAN et al. 2007).
- **Forests with *Quercus robur*** enjoy specific site conditions (Fig. 2b). They are found in locations with warm, dry summers but periodically wet, loamy sites, such as the Pannonian lowlands of northwest Romania (*Molinio caeruleae-Quercetum roboris* Scamoni et Passarge 1959; habitat type 9190) (RAȚIU et al. 1977, KARÁCSONYI 1995, DONIȚĂ et al. 2008). Enclaves of *Quercus* forests comprising *Quercus robur* mixed with *Q. petraea* and *Acer tataricum* are also found in the inner-Carpathian basins in the Southeastern Carpathians, in locations with late frosts and loamy/sandy soils.
- Carpathian **colline mixed forests with *Quercus petraea*** as dominant tree species dominate the sunny slopes and ridges of the colline zone across large areas of northwestern Romania (Fig. 2c). They occur on acidic to moderately acidic brown earth (INDREICA 2011, 2012) between 450 and 700 m above sea level, with annual average temperatures of 7 to 8 °C and annual precipitation of 600 to 750 mm (COLDEA & POP 1996). Apart from *Quercus petraea*, the species-rich tree layer also includes *Prunus avium*, *Acer campestre*, *A. tataricum*, *Sorbus torminalis* and other tree species. Large areas of colline mixed forest with *Quercus petraea* and *Q. dalechampii* are also found at the foot of the Southern Carpathians and highlands of Moldavia and Dobrudja, with more submediterranean species on the southern side (DONIȚĂ 1968, BOHN et al. 2002/2003).
- **Forests with *Quercus cerris* and *Q. frainetto*** (habitat type 91M0, *Quercetum frainetto-cerris* Rudski 1949) are found in the western parts of Transylvania as far as the Someş uplands, sporadically scattered among terraces and gentle sunny slopes on weakly acidic brown to red-brown, part-pseudogley, part-podzol soil on sedimentary rock (Fig. 2d). Elevations range from (250) 300 to 500 (600) m above sea level. Average annual temperatures in this weakly submediterranean climate range between 8 and 11 °C. *Quercus cerris* and *Q. frainetto* dominate, in some cases mixed with *Q. polycarpa*, *Acer campestre* and *A. tataricum* (POP 1942, 1945, COLDEA & POP 1996, DONIȚĂ et al. 2008). Forests with *Q. cerris* and *Q. frainetto* are also widespread in Wallachia, and *Q. frainetto* forms very few extrazonal stands in Southern Moldavia (OPREA & SÎRBU 2021) and Southern Dobrudja (PARINCU 1997).

Fig. 2. a) Steppe in transition to forest steppe. Dobrudja, 160 m a.s.l., 01.06.2014. **b)** Forest with *Quercus robur* on wet, humus-rich soil. Satu Lung, district Maramureş, 480 m a.s.l., 18.07.2010. **c)** Oak Forest (*Quercus petraea* and *Q. robur*), with *Anemone nemorosa* in the herb layer. Vila Franka, Sighişoara, district Mureş, 470 m a.s.l., 23.03.2014. **d)** Xerothermic forest with *Quercus cerris* and *Q. frainetto*. Jablanița, district Caraș-Severin, Banat, 290 m a.s.l., 24.10.2019 (Photos: L. Rákosy).

Abb. 2. a) Waldsteppe im Übergang zu Steppe. Dodrudscha, 160 m NN, 01.06.2014. **b)** *Quercus robur*-Wald auf sauren, nassen bis anmoorigen Böden. Satu Lung, Maramureş, 480 m NN, 18.07.2010. **c)** Eichenwald mit *Quercus petraea* und *Q. robur*, Bodenvegetation mit *Anemone nemorosa*. Vila Franka, Schäßburg, 470 m NN, 23.03.2014. **d)** Xerothermer Wald mit *Quercus cerris* und *Q. frainetto*. Jablanița, Distrikt Caraș-Severin, Banat, 290 m NN, 24.10.2019 (Fotos: L. Rákosy).

2.1.2 Forests with Oriental hornbeam (*Carpinus orientalis*)

In the Southwest (Banat, Oltenia, Muntenia) with its mild winters, forests with *Carpinus orientalis* and *Quercus pubescens* (*Acantho longifolii-Quercetum pubescentis* Jakucs et Fekete 1958) indicate the transition to the illyrian-influenced, submediterranean climate (Fig. 3a, b). Other tree species are *Fraxinus ornus*, *Acer monspessulanum*, *Corylus colurna* and *Celtis australis*. *Syringa vulgaris* (*Syringo-Carpinetum orientalis* Jakucs 1959) occurs at the edaphic drought limit of forests (cf. JAKUCZ et al. 1959, JAKUCS 1961, BÂNDIU et al. 1995, MATACĂ 2003, 2005, ARSENE et al. 2006, INDREICA in COLDEA et al. 2015).

In the Dobrudja with its relatively continental climate such forests occur close to the Black Sea coast with its milder winters (*Paeonio peregrinae-Carpinetum orientalis* Doniţă 1970), in the North of Dobrudja (Măcin Mountains), and in the plateaux of Babadag, Casimcea, and Southern Dobrudja (Fig. 3c, d). Other tree species found here include *Quercus pubescens*, the east Pontic *Fraxinus excelsior* subsp. *coriariifolia*, *F. ornus*, *Ulmus minor*, *Acer tataricum*, *Sorbus torminalis* and *S. domestica* (DONIŢĂ 1968, 1970). An isolated stand with *Carpinus orientalis* exists near Roşcani village (Iaşi country) (HOREANU 1981). In the Transylvanian tableland also isolated stands of *F. ornus* exist (NEGREAN et al. 2017, KOVÁCS 2019).

Fig. 3. a) Rocks with open forest of *Carpinus orientalis*, *Fraxinus ornus* and *Syringa vulgaris*. Slope to Danube river, Iron Gate near Dubova, district Mehedinţi, 200 m a.s.l., 26.07.2006. **b)** Oriental Hornbeam (*Carpinus orientalis*) with fruits. Banat, Iron Gate, 02.07.2014. **c)** Forest with *Carpinus orientalis*, *Quercus polycarpa* and *Fraxinus ornus*. Cheile Dobrogei, Dobrudja, district Constanţa, 120 m a.s.l., 07.06.2014. **d)** Forest margin with *Carpinus orientalis* and *Paeonia peregrina*. Northern Dobrudja, Ciucurova-Forest, district Tulcea, 200 m a.s.l., 16.05.2005 (Photos: a, c, d) L. Rákosy, b) A. Reif).

Abb. 3. **a)** Felshang mit lichtem Wald aus *Carpinus orientalis*, *Fraxinus ornus* und *Syringa vulgaris*. Donauhang am Eisernen Tor bei Dubova, 200 m NN, 26.07.2006. **b)** Orientalische Hainbuche (*Carpinus orientalis*) fruchtend. Banat, Eisernes Tor, 02.07.2014. **c)** Wald mit *Carpinus orientalis*, *Quercus polycarpa* und *Fraxinus ornus*. Cheile Dobrogei, Dobrudscha, 120 m NN, 07.06.2014. **d)** Waldrand mit *Carpinus orientalis* und *Paeonia peregrina*. Nord-Dobrudscha, Ciucurova-Wald, 200 m NN, 16.05.2005 (Fotos: a, c, d) L. Rákosy, b) A. Reif).

2.1.3 Forests with oaks (*Quercus* spp.) and hornbeam (*Carpinus betulus*)

Forests with *Quercus* spp. and *Carpinus betulus* develop on less extreme sites, i.e. those with a better water supply than oak forests (Fig. 4a). *Quercus robur-Carpinus* forests occur mostly on lowlands (plains) whereas *Q. petraea-Carpinus* forests are found on colline and sub-montane hills (*Melampyro bihariensi-Carpinetum* Soó 1964 em. Coldea 1975, *Lathyro hallersteinii-Carpinetum* Coldea 1975). The shade-giving and hence shade-tolerant, relatively late-frost-resistant hornbeam is dominant here, often together with *Quercus petraea* on drier soils (habitat type 91Y0) (HORVAT et al. 1974, DONIȚĂ et al. 1990, 2005, 2008, CHIFU et al. 2014, COLDEA et al. 2015). Mixed tree species include *Tilia cordata*, *Acer campestre* and *Prunus avium*.

The structure of many stands in forests with *Quercus* spp. and *Carpinus betulus* show signs of coppicing and coppice-with-standards management (Fig.4b); the hornbeam in the understorey, which re-sprout from the stump, were mainly used for firewood. In the overstorey, *Quercus robur*, once vitally important and widely promoted, supplied construction

timber and mast for pig feed. Forests with *Quercus* and *Carpinus* form the zonal vegetation on medium to deep soils, often rich in clay, in the Transylvanian Highlands, Moldavia and Wallachia. Further occurrences of *Quercus* and *Carpinus* forests are found in the foothills of the Eastern Carpathians and in Moldavia (ENCULESCU 1938, PAȘCOVSCHI & LEANDRU 1958, MAYER 1984, DONIȚA et al. 1990, 1992, IVAN et al. 1993, STOICA et al. 2017).

Illyric forests with *Quercus* and *Carpinus* (*Asperulo taurinae-Carpinetum betuli* Soó et Borhidi in Soó 1962, = *Querco cerridis-Carpinetum betuli* Boşcaiu 1966 et al. p.p.; habitat type 91L0) are characterised by *Q. petraea*, *C. betulus* and thermophilic species such as *Q. cerris*, *Tilia tomentosa* and sub-Mediterranean species of the herbaceous layer such as *Aremonia agrimonioides*, *Ruscus aculeatus*, *R. hypoglossum*, *Asperula taurina* subsp. *leucanthera*, *Galium kitaibelianum*, *Helleborus odorus*, *Paeonia mascula* and *Erythronium dens-canis* var. *niveum*.

The naturally widespread Dacian *Quercus-Carpinus betulus* forests (*Lathyro hallersteinii-Carpinetum* Coldea 1975; habitat type 91Y0) thrive at colline and submontane altitudes. However, most of them have been converted into agricultural land or semi-open oak-rich pastures.

In Dobrudja, above an altitude of around 250 m, we find Pontic oak-hornbeam forests with *Carpinus betulus*, *Tilia tomentosa* and *Quercus dalechampii* (*Tilio tomentosae-Carpinetum betuli* Doniţă 1968) (DONIȚĂ 1968, DONIȚĂ et al.2008).

2.1.4 Beech forests: *Fagus sylvatica* and *Fagus sylvatica* mixed forests

The increase of water availability and decrease of late frosts risks, both favored by combinations of altitude, air mass flow, latitudes, soil texture, forest mass effect, allows *Fagus sylvatica* to survive even dry years. At submontane altitudes, *F. sylvatica* forms mixed stands with the more thermophilic, relatively drought- and late frost resistant *Carpinus betulus* and displaces this shorter-lived, slower-growing tree species on sites with better water supply, such as on shady slopes or moister soils (except flooded or high-watertable sites) (Fig. 4c, d). The highly shade-tolerant *F. sylvatica* therefore forms the zonal vegetation across large areas (PAUCĂ-COMĂNESCU 1989). It displaces *C. betulus* and light-dependent species such as *Quercus* spp. to extrazonal drier soils, or late-frost prone sites such as deep valleys or topographic depresssions.

In the Transylvanian Highlands, the transition zone between *Quercus-Carpinus betulus* and *Fagus sylvatica* forests is located between 500 and 700 m (BORZA 1959, DONIȚĂ et al. 1990, 2008). This limit is modified by the local climate, especially due to topographical differences in irradiation (and hence evaporation), as well as by the soil's capacity to store water. It is difficult to reconstruct the natural lower limit of *F. sylvatica* today, because it has moved upwards as a result of historical coppicing practices, favouring the superior ability of *Quercus-Carpinus betulus* forest species to resprout from the stump. Today, some *F. sylvatica* forests are still found at 150 m a.s.l. on shady slopes and valley bottoms in Southwestern Romania (OPREA et al. 2011), reaching the lowest altitudes along the Danube Valley (Orşova, Moldova Nouă; about 60 m a.s.l.) (BELDIE 1952).

In Bucovina and Moldova, *F. sylvatica* extends far to the Northeast, close to its eastern limit along the Nister river, which is presumably caused by more frequent late frosts, combined with summer drought. Surprisingly, these forests retain the ability to form tall, productive stands near their macroclimatic eastern limit. As *F. sylvatica* thrives in both acidic and calcareous soils, it associates with a range of different (tree) species across several widespread forest types. Carpathian species such as *Cardamine glanduligera*, *Symphytum*

cordatum, *Ranunculus carpaticus*, *Hepatica transsilvanica*, *Pulmonaria rubra*, *Aconitum moldavicum*, *Leucanthemum rotundifolium* (= *L. waldsteinii*), *Lathyrus hallersteinii* and *Hieracium transsylvanicum* occur in the understorey. Occurrences of "pre-Alpine - pre-Carpathian" species such as *Aposeris foetida*, *Salvia glutinosa* and *Veronica urticifolia* are also worth noting. *Fagus sylvatica* forests on base-rich soils offer a particular richness of species, including broad-leaved trees such as *Acer pseudoplatanus* and *Ulmus glabra*.

Illyrian *F. sylvatica* forests are found in the Southwestern Carpathians with their milder winters, while Dacian *F. sylvatica* forests occur in other regions. The following forest associations have been recorded:

- *Lathyro veneti-Fagetum* Chifu et al. 2006 (= *Galio schultesii-Fagetum* Chifu et Ştefan 1994; habitat type 91V0), at 200 to 400 m in SE Romania with its mild winters, colline to submontane. Also in hilly areas in Moldova.
- *Aremonio agrimonoidis-Fagetum* Boşcaiu in Resmeriţă 1972: in Banat (SW Romania) on moderately acid brown soils (mesotrophic), colline to montane sites (habitat type 91K0).
- *Symphyto cordati-Fagetum* Vida 1959: widespread, on mesotrophic to eutrophic soils, weakly acidic, montane in the southeast Carpathians, habitat type 91V0.
- *Hieracio transsilvanici-Fagetum* (Vida 1963) Täuber 1987, widespread on (mesotrophic to acidic soils; habitat type 9110).
- *Phyllitidi-Fagetum* Vida (1959) 1963 (azonal on skeleton-rich soils on limestone, shady slopes; habitat type 91V0).

The slow-growing, undergrowth-rich beech forests on skeleton-rich or rocky rendzina, especially of calcareous soils (*Epipactido microphyllae-Fagetum* Resmeriţă 1972; = *Seslerio rigidae-Fagetum* Sóo in COLDEA et al. 2015) enjoy a special status, occurring e.g. in the southern and southwestern Carpathians (VIDA 1963). These forests are the equivalent to Central Europe's orchid or sedge beech forests (*Carici-Fagetum* Moor 52, habitat type 9150). In the Cerna Valley and in the deep side valleys of the Danube Gorge near the "Iron Gates", beech forests provide shelter to several thermophilic species that are typical of the region, such as *Daphne laureola*, *Dioscorea communis*, *Asperula taurina* subsp. *leucanthera*, *Helleborus odorus*, *Ruscus hypoglossum* and *Scutellaria altissima* (COLDEA et al. 1970).

A notable, disjunct small patch of beech is found near the Danube in the Dobrudja region near Luncaviţa in the Măcin mountains, in the "Valea Fagilor" nature reserve (habitat type 91X0*). Even here, at the southeastern edge of its distribution, beech is dominant or co-dominant, mixed with *Carpinus betulus*, *Tilia tomentosa* and *T. cordata* (DIHORU 1962, DONIŢĂ et al. 2008, GAFTA & MOUNTFORD 2008, OPREA et al. 2011). This beech stand is formed by *Fagus* × *taurica* (Crimean beech) (*Symphyto taurici-Fagetum taurici* Oprea et al. 2011) (OPREA et al. 2011, WILLNER et al. 2017).

Other notable occurrences include the subalpine stands of pure *Fagus sylvatica*, such as those found in the Southern Carpathians (Godeanu Mountains, Parâng Mountains in the Gorj district). The lack of long-lasting frost periods, abundant snow in winter and summer drought prevent the formation of a subalpine *Picea abies* forest zone, and allows beech to form the climatic tree line (BORHIDI 1971, HORVAT et al. 1974, STANISCI et al. 2000, SURINA & RAKAJ 2007). This is the equivalent of the tree line in the Southern Alps and mountain ranges of southern and western Central Europe. To some extent, this argumentation also applies to the virgin *F. sylvatica* forests in Semenic Mountains at the sources of the Rivers

Fig. 4. a) *Carpinus betulus* forest, southwest of Agniţa, district Sibiu/Transilvania, 530 m a.s.l. 05.08.2013. **b)** *Carpinus betulus* forest. Previous coppice forest in transition to high forest. Viscri, district Braşov/Transilvania, 660 m a.s.l., 06.08.2013. **c)** Forests with *Quercus* spp. and *Tilia tomentosa* on the sunny slopes, *C. betulus* on the shady slopes, and *Fagus sylvatica* at higher elevation and shady slopes in gullies. Băile Herculane, district Caraş-Severin, 160–600 m a.s.l., 23.06.2015. **d)** Beech forest. Valea Sapartoc near Sighişoara, district Mureş, 540 m a.s.l., 24.06.2021. **e)** Virgin beech forest, montane to subalpine zone. Semenic Mountains, 1500 m a.s.l., 21.06.2015. **f)** Beech-fir-spruce mixed mountain forest (left). The valuable conifers were extracted. In the frost hollows of dolines, spruce dominates (right). Mununa/Apuseni mountains, 1100 m a.s.l., 08.10.2006 (Photos: a, d) L. Rákosy, b, c, e, f) A. Reif).

Abb. 4. a) *Carpinus betulus*-Wald südwestlich von Agnetheln (Agniţa)/Siebenbürgen, 530 m NN, 05.08.2013. **b)** *Carpinus betulus*-Wald. Alter Stockausschlag in Überführung zum Hochwald. Viscri /Siebenbürgen, 660 m NN. 06.08.2013. **c)** Am Sonnenhang dominieren Wälder mit *Quercus* spp. und *Tilia tomentosa*, am Schatthang mit *C. betulus*, und in den Hochlagen und Rinnen mit *Fagus sylvatica*. Herkulesbad, 160–600 m NN, 23.06.2015. **d)** Buchenwald. Valea Sapartoc bei Schäßburg, 540 m NN, 24.06.2021. **e)** Buchen-Urwald der montanen bis zur subalpinen Höhenstufe. Semenic-Gebirge, 1500 m NN, 21.06.2015. **f)** Montaner Bergmischwald mit Buche, Tanne, Fichte (links). Das Nadelholz wurde großenteils bereits entnommen. In den Frostlöchern der Dolinen dominiert die Fichte (rechts hinten). Mununa/Apuseni Gebirge, 1100 m NN, 08.10.2006. (Fotos: a, d) L. Rákosy, b, c, e, f) A. Reif).

Nera and Nergănița (Fig. 4e). These forest stands are comprised almost entirely of pure *F. sylvatica*, which (inexplicably) contains no *Abies alba* even at the montane zone, and beech is reaching the tree line at 1500 m a.s.l.

Regarding the accompanying flora, the Carpathian *Fagus sylvatica* forests (*Symphyto-Fagion* Vida 1959) are home to many endemic Dacian and Dacian-Balkan species such as *Aconitum moldavicum*, *Cardamine glanduligera*, *Pulmonaria rubra* and *Symphytum cordatum* (DONIȚĂ 1989, STOICULESCU 1983, 2007, KLIMENT et al. 2016). *Hepatica transsilvanica* appears to be an endemic tertiary relict species (POP 1976, SÂRBU et al. 2013), whose closest relative is *H. falconeri* from North of Pakistan (MATACĂ 2003) or *H. henryi* from China (POP 1976). A similarly disjunct tertiary relic is *Galium baillonii*, which occurs in the *Fagus sylvatica* forests of the Southern Carpathians (SCHNEIDER-BINDER 1971).

2.1.5 Beech-fir-spruce mixed mountain forests (*Fagus sylvatica*, *Abies alba*, *Picea abies*)

Fagus sylvatica mixes with *Abies alba* in the montane zone (Fig. 4f). The lower limit of this mixed mountain forest occurs in the Eastern Carpathians at around (470-) 700 (-1120) m a.s.l. (MARDARI et al. 2015). The upper limits for these mixed mountain forests dominated by *Fagus sylvatica* and *Abies alba* (*Pulmonario rubrae-Abietetum* Beldie ex Coldea 2015) are found at around 1300 m in the Eastern Carpathians, and around 1400 m in the Southern Carpathians (MEUSEL 1968, DONIȚĂ et al 1990, 2005, OPREA et al. 2011). Mixed montane forests on soils with increased nutrient/nitrogen content and moisture were described as *Leucanthemo waldsteinii-Fagetum* (Soó 1964) Täuber 1987, with *Acer pseudoplatanus* on the nutrient rich sites (COLDEA et al. 2015).

Beech forests with disjunct distribution of *Taxus baccata* in the understorey (habitat types 91V0) were undoubtedly more widespread in the past. Today they occur in the montane Southeastern Carpathians (Cenaru/Vrancea county), the Şerbota Valley of the Făgăraș Mountains, Suceava Highlands, Postăvaru Mts, Nemira Mts, Parâng Mts, Piatra Craiului Mts.

In the upper montane (oreal) zone, *Fagus sylvatica* and *Abies alba* are joined by *Picea abies*. On acidic silicate soils montane fir-spruce forests with only a minor share of beech can occur ("Abietetum", e.g. *Hieracio rotundati-Abietetum* [Borhidi 1971] Coldea 1991, *Festuco drymeiae-Abietetum* Filipaş et al. 2013). On marlacious flysch in the Eastern Carpathians, *Abies alba* and *Picea abies* exhibit "excellent growth performance" (BARBU & BARBU 2005, MARDARI et al. 2015).

2.1.6 Spruce (*Picea abies*) forests

In the montane zone, spruce forest can be found close to the edges of bogs or on late frost prone sites, replacing the mixed beech-fir-spruce forest (Fig. 4f). Above this mixed mountain forest, *Picea abies* forms a coniferous forest belt in the lower subalpine zone, caused by shorter vegetation periods and less summer drought (*Doronico columnae-Piceetum* Coldea 2002, *Hieracio transsilvanici-Piceetum* Pawł. et Br.-Bl. 1939, habitat type 9410). The spruce forest belt extends to the climatic tree line between 1600 m a.s.l. (Maramureş in the Northeastern Carpathians) and 1900 m (Southern Carpathians) (Fig. 5a, b).

In the Eastern Carpathians spruce forests naturally dominate in a 200 km long, 75 km wide zone between approximately 1100 and 1700–1800 (1900) m a.s.l. In the Southern Carpathians, the sub-alpine spruce belt becomes increasingly narrower, dissolving into isolated stands to the West, and disappearing in the Parâng and Godeanu mountains (western South Carpathians) (MEUSEL 1968, RESMERIȚĂ 1975, DONIȚĂ et al. 1990, 2005).

Several spruce forest associations can be found depending on the geology (COLDEA 1991, DONIȚĂ et al. 2008, GAFTA & MOUNTFORD 2008, COLDEA et al. 2015): The *Soldanello oreodoxae-Piceetum* Coldea et Wagner 1968 corr. Coldea 2015 forms the tree line on base-poor siliceous soils (Apuseni Mountains). On moist, nutrient-rich soils forb-rich spruce forests (*Chrysanthemo rotundifolii-Piceetum* Krajina 1933) were described, they correspond to the *Adenostylo-Piceetum* Hartmann 1953 of the Alps (cf. MAYER 1984).

In the montane zone, the less competitive but more stress-tolerant spruce, sometimes accompanied by *Pinus sylvestris*, also forms azonal forests on special sites such as the borders of mires, on bottom parts of boulder slopes, or in late frost prone depressions. On such sites, *Fagus sylvatica* and *Abies alba* cannot thrive due to the wet or shallow soil or late frosts.

2.1.7 Subalpine shrubland with dwarf pine (*Pinus mugo* subsp. *mugo*)

In the upper subalpine zone between ca 1700 and 2000 m a.s.l., dwarf pine shrubland with *Pinus mugo* subsp. *mugo* (IVAN et al. 1993, DONIȚĂ et al. 2005, 2008, BORATYŃSKA et al. 2015) replaces the coniferous forests (Fig. 5c), with the Balkan dwarf *Ericaceae*-shrubs *Rhododendron myrtifolium* and *Bruckenthalia spiculifolia* in the undergrowth (habitat types 4070*). The green alder *Alnus viridis* thrives in oreal and subalpine valleys, usually prone to avalanches, with wetter and more unstable sites compared to dwarf pine, e.g. in the Bucegi Mountains, Făgăraș, Iezer-Păpușa, Țarcu-Petreanu, Godeanu, Piatra Mare, Rodnei (MEUSEL 1968, COLDEA 1985).

2.2 Azonal forests and shrubland of extreme sites

On sunny, shallow, rocky sites drought becomes the dominant site factor. Forests are comprised of edaphic drought-tolerant species (2.2.1 to 2.2.3). On unstable slopes valuable broadleaf trees tend to dominate (2.2.4). Riparian habitats are characterised by periodical flooding. The location and size of the water body, the duration, height, time, frequency and flow rate of the flood, the chemistry of the water body and redistribution processes (erosion, sedimentation) create phytosociologically diverse, dynamic, complex habitats with riparian forest and shrubland (2.2.5 to 2.2.9).

2.2.1 Black pine (*Pinus nigra*) forests

Black pine (*Pinus nigra* var. *banatica*; ANASTASIU et al. 2001) dominates on the skeleton-rich calcareous soils of Southwestern Romania (Banat, Oltenia) in form of the *Genisto radiatae-Pinetum pallasianae* Resmeriță 1972 (habitat type 9530*) and extends to altitudes of 1000 m above sea level (BOȘCAIU & BOȘCAIU 1999) (Fig. 5d).

2.2.2 Scots pine (*Pinus sylvestris*) forests

Forests of *Pinus sylvestris*, e.g. the *Daphno blagayanae-Pinetum sylvestris* Coldea et Pop 1988 from Southern Carpathians, can be found on rocky, shallow soils in the montane zone. On such sites, other tree species like beech or fir are not able to survive. Such forests are relics of drier & colder post-glacial times on those extreme sites, e.g. in Cozia, Parâng or Vâlcan Mountains. The pine forests occurring on limestone (*Seslerio rigidae-Pinetum* Csűrös et al. 1988, *Campanulo carpaticae-Pinetum* Guşuleac 2015) (COLDEA et al. 2015) are the equivalent of *Erico-Pinetea* forests in the Alps. Other sites are the late frost prone,

Fig. 5. a) *Picea abies* forest along the Bâlea river valley, Southern Carpathians, 2100 m a.s.l. (Photo: 3.08.2017, A Reif). **b)** *Picea abies* forest in Piatra Craiului National Park, Southern Carpathians, 1750–1950 m a.s.l. (Photo: 10.08.2019, L. Rákosy). **c)** *Picea abies* forest in transition to "Krummholz" with *Pinus mugo* subsp. *mugo*. Subalpine zone. Ceahlău Mountains, Eastern Carpathians (Photo: 20.08.2006, A. Oprea). **d)** Black pine forest with *Pinus nigra* var. *banatica* on shallow, rocky soils. Submontane and montane zone. Domogled, Mehedinţi Mountains, Southwest Carpathians, 600 m a.s.l. (Photo: 23.06.2015, A. Reif). **e)** Isolated stand of *Pinus cembra*, surrounded by *P. mugo* subsp. *mugo*. Gemenele Lake, Retezat Mt., 1900 m a.s.sl. (Photo: 23.06.2019, I. Ghira). **f)** *Larix decidua* subsp. *carpatica* on shallow, rocky soil. Ceahlău Mountains, Nature reserve "Poliţa cu Crini", Eastern Carpathians, 1450 m a.s.l. (Photo: 18.08.2007, A. Oprea).

intramontane basins in the Eastern Carpathians (COLDEA & POP 1988, DONIȚĂ et al. 2008). The *Leucobryo-Pinetum* Matusk. 1962 is found on extremely nutrient-poor, acidic silicate sites (habitat type 91Q0). *Pinus sylvestris* forest can also be found on nutrient-poor, acidic bog edges in the Eastern Carpathians.

2.2.3 Subalpine larch (*Larix decidua* subsp. *carpatica*) and stone pine (*Pinus cembra*) forests

In the subalpine zone, a few disjunct areas with relic forms of European larch (*Larix decidua*) and *Pinus cembra* occur on shallow, acidic soils, scattered and surrounded by spruce forest (habitat type 9420) (MEUSEL 1968, BLADA 2008, FĂRCAȘ et al. 2013) (Fig. 5e, f). However, the Carpathians lack a continuous larch-pine belt as found in the Central Alps.

2.2.4 Broadleaved mixed forests

On unstable soils on sloping ground, zonal vegetation is replaced by broadleaved forest types (*Aceri-Fraxinetum* Tx. 1937, habitat type 9180*) with species such as *Acer pseudo-platanus*, *Fraxinus excelsior*, *Ulmus glabra* and *Tilia cordata*, which have the ability to resprout.

2.2.5 Black alder (*Alnus glutinosa*) forests

Forests of *Alnus glutinosa* occur along streams and small rivers up to the submontane zone (*Stellario-Alnetum glutinosae* Lohmeyer 1957; habitat type 91E0*). *Alnus glutinosa*-forest can also be found on permanently wet peat or gley soil (*Alnion glutinosae* Malc. 1929).

2.2.6 Grey alder (*Alnus incana*) forests

Alnus incana in the *Telekio speciosae-Alnetum incanae* Coldea 1990 dominates the submontane and montane floodplains, mixed with ash and *Salix fragilis*. *Salix triandra*, *S. viminalis* and (rarely) *S. pentandra* occur in the riparian willow pioneer shrubland and forests of the submontane zone in the Carpathians (habitat type 91E0*).

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Abb. 5. a) *Picea abies*-Wald im Bâlea-Tal, Süd-Karpaten, 2100 m NN (Foto: 03.08.2017, A. Reif). **b)** *Picea abies*-Wald im Piatra Craiului Nationalpark, Süd-Karpaten, 1750–1950 m NN (Foto: 10.08.2019, L. Rakosy). **c)** *Picea abies*-Wald im Übergang zur Krummholzzone mit *Pinus mugo* subsp. *mugo* in der oberen subalpinen Höhenstufe. Ceahlau-Gebirge, Ost-Karpaten (Foto: 20.08.2006, A. Oprea). **d)** Schwarzkiefern-Wald mit *Pinus nigra* var. *banatica* auf flachgründigem Felsboden. Submontane und montane Höhenstufe. Domogled, Mehedinţi-Gebirge, SW-Karpaten, 600 m NN (Foto: 23.06.2015, A. Reif). **e)** Isoliertes Vorkommen von *Pinus cembra*, umgeben von *P. mugo* subsp. *mugo*. Gemenele-See, Retezat-Gebirge, 1900 m NN (Foto: 23.06.2019, I. Ghira). **f)** Lärchenwald mit *Larix decidua* subsp. *carpatica* auf flachgründigem Fels. Ceahlău-Gebirge, Naturschutzgebiet „Poliţa cu Crini“, Ost-Karpaten, 1450 m NN (Foto: 18.08.2007, A. Oprea).

2.2.7 Tamarisk (*Myricaria germanica*) pioneer copses

On fast-flowing mountain rivers (braided river zone), periods with flood are relatively short, while the flow rate and sediment turnover are more pronounced, characterised by erosion, transport and sedimentation of gravel. The impacts of these factors on the vegetation vary widely depending on their location between the main river channels and the edge of the floodplain. The vegetation is characterised by pioneer copse of the low-growing shrub *Myricaria germanica* (Fig. 6a). This transitions into pioneer stands of *Salix purpurea*, sporadically and locally mixed with *S. eleagnos*, and on less extreme sites forests with grey alder (*Alnus incana*). Some mountain valleys also contain stands of *Hippophaë rhamnoides* (habitat type 3240).

2.2.8 Floodplain pioneer forests with poplar (*Populus* spp.) and willow (*Salix* spp.)

In the lower reaches of large rivers and streams (meander zone), the inundation periods are longer, flow rate is slower, and fine-grained sediments (loam) are deposited. Pioneer copses of the *Salicaceae* family colonise the mineral soils created by the natural river dynamics in the gallery forest closer to the mean water level (Fig. 6b). Forests of silver willow (*Salix alba*), locally also *S. fragilis*, black poplar (*Populus nigra*), silver poplar (*P. alba*) and grey poplar (*P.* × *canescens*) are widespread, for example, along the larger rivers (Mureş, Prut, Danube, Jiu, Olt, Ialomiţa, Siret) and in the Danube delta (habitat type 92A0).

At the lower Danube softwood pioneer forests are mainly formed by silver willow and silver poplar (OPREA 2004). In floristic terms, however, they are more closely related to Mediterranean softwood gallery forests than to the forests of Southeast Central Europe (SCHNEIDER et al. 2009). These pioneer forests are in contact with copses of *Salix triandra* and *Tamarix ramosissima* under long-lasting flood stress. Tamarisks are found in the Danube from the Olt-Danube junction to the Danube Delta and in the lower reaches of the rivers Olt, Ialomița, Buzău and Siret. They can form extended stands in the brackish water of the Danube delta (OPREA 2004). Larger stands of *Hippophaë rhamnoides* are also found there in some areas (habitat type 92D0). It must be assumed that many of them were planted to stabilize the soil.

2.2.9 Riparian hardwood forests

Riparian hardwood forests with *Quercus robur*, *Ulmus laevis*, *U. minor*, *Fraxinus excelsior* and *F. angustifolia* subsp. *oxycarpa* occur on slightly elevated places formed from sediment along major rivers, incl. Danube. Large populations of *Vitis sylvestris* are still found to this day (Fig. 6c). The climber *Periploca graeca* thrives locally at the Danube riverside and its islands, and especially in the delta, with the Danube forming the northern limits of its range. The riparian hardwood forests of Southeast Romania are unique, especially those in the dunes of Letea and Caraorman sand banks in the Danube delta (Fig. 6d). Tree species such as *Quercus pedunculiflora*, *Fraxinus angustifolia* subsp. *oxycarpa* and *F. pallisae* occur here in the *Fraxino pallisae-Quercetum pedunculiflorae* Oprea 1997 (KRAUSCH 1965, SANDA et al. 1998, OPREA 2004, COLDEA et al. 2015) (habitat type 91F0). Smaller areas of riparian hardwood forest are also found upstream in the Lower Danube region (SCHNEIDER et al. 2009).

Fig. 6. a) *Myricaria germanica* forms pioneer shrubland on riparian gravel along fast-flowing mountain rivers and streams. Slătioara qvasi-virgin forest, Rarău Mountains, Eastern Carpathians, 08.08.2013, 800 m a.s.l. **b)** *Salix alba*-forest, inundated for months by extremely long-lasting inundations as in 2005. – Delta of Danube river between Tulcea and Caraorman, 17.05.2005. **c)** Wild grape (*Vitis sylvestris*) is able to climb up to the crowns of large *Salix alba* trees. Delta of Danube river, Fortuna Lake, 20.05.2005. **d)** Riparian forest with *Quercus robur* subsp. *pedunculiflora*. Delta of Danube river, Letea forest, 18.05.2005 (Photos: A. Reif).

Abb. 6. a) Die *Myricaria germanica* bildet Pioniergebüsche auf grobkiesigen Böden der Furkationszone von Gebirgsbächen und -flüssen. Slătioara, Rarău Gebirge, Ost-Karpaten, 800 m NN, 08.08.2013. **b)** *Salix alba*-Wald. Bei extremen Hochwässern wie im Jahr 2005 ist der Wald monatelang überflutet. Donau-Delta zwischen Tulcea und Caraorman, 17.05.2005. **c)** Die Wilde Weinrebe (*Vitis sylvestris*) ist in der Lage, in die Krone großer *Salix alba*-Bäume hochzuwachsen. Donau-Delta, Fortuna See, 20.05.2005. **c)** Auwald mit *Quercus robur* subsp. *pedunculiflora*. Donau-Delta, Letea-Wald, 18.05.2005 (Fotos: A. Reif).

3. Forest and nature conservation

Today, Romania is no longer a forest-dominated country. Forests now cover only around 30% of its land area (FOREST EUROPE 2020). Many of the remaining forests in the lowlands have been intensively used since centuries, often in form of coppice forest or coppice forest with standards, combined with wood pasture, charcoal production, and collection of non-timber forest products. In the mountains, remoteness and inaccessibility allowed the persistence of "high-conservation-value forests" with primary and old-growth characteristics (PĂTRU-STUPARIU et al. 2013, MUNTEANU et al. 2016, 2021). BIRIŞ (2017) estimated between 150.000 and 200.000 ha of virgin forests in Romania which represent about two-third of the remaining temperate virgin forests of Europe (LUICK et al. 2021a, b, c) (Fig. 7a, b).

MUNTEANU et al. (2021) identified 738.000 ha of "high-conservation-value forests" with primary and old-growth characteristics, 387,000 ha of them under high anthropogenic pressures.

Various sources (quoted and compiled in BIRIȘ 2017) reported on the existence of impressive virgin forests in the Southern Carpathians before the Second World War and at the start of the communist era. Initially, changes were gradual under the communist regime, which nationalised all forests in 1950. Many valleys in the Southern Carpathians remained inaccessible. Between 1960 and 1980, however, the state invested in a development programme, and also virgin and quasi-virgin forests were clearfelled. After the collapse of the communist regime and the following societal and economical crisis, irregular and illegal forest uses increased (VEEN et al. 2010, MUNTEANU et al. 2016). In 2007 Romania joined the EU, and its forest resources became attractive for commercial exploitation by foreign companies. Between 2001 and 2019, according to a study of GLOBAL FOREST WATCH (2020), Romania lost about 350,000 ha of virgin and quasi-virgin forests through illegal and also legal logging by false interpretation of the legal framework. This is proved by a recent study from the Joint Research Centre of the EU (JRC) indicating for the period between 2014 and 2018 a massive increase of timber harvesting in many EU countries, including large-scale clearcuttings in Romania (MUNTEANU et al. 2016, CECCHERINI et al. 2020) (Fig. 7c, d).

At present, the protection status of Romania's virgin and quasi-virgin forests is weak. Supplement S2 contains a list of Romania's 13 national parks together with key administrative data. An analysis of the official information available relating to management zones clearly shows that:

- three out of 13 national parks have no designated core zones, according to the official information available,
- six out of 13 national parks have only very small core zones, and
- only four national parks contain significant areas designated as strict protection zones: Piatra Craiului National Park (6,291 of a total of 14,766 ha); Retezat National Park (1,932 of 38,138 ha); Semenic-Cheile Carașului National Park (4,271 of 36,051 ha); Cheile Nerei-Beuşnița National Park (4,271 of 29,386 ha).

According to the IUCN criteria (recommendations) for "national parks" protection category II 75% of the land should be designated as an unmanaged core zone. Not one national park in Romania follows these recommendations in its handling and interpretation of the existing zones (strict protection zone = core area). The administrations of the national parks except NP Ceahlău in Moldavia in the Northeast are under the full control of and financially dependent on the Romsilva State Forestry Administration. It therefore is not surprising that the national park administrations have not commented on these situations, nor have they objected to the mode and intensity of silvicultural interventions in protected areas. They are under latent pressure, because their jobs and budgets effectively rely on income generated from logging in their park. Even against the widely documented large-scale interventions within the perimeters of core zones the park authorities have not reacted.

The Romsilva State Forestry Administration appears to be the lynchpin of all economic activities and policies relating to Romania's forests. Currently, Romsilva manages about 3.4 million hectares of forest, i.e. around 52% of the total forested area in Romania. Romsilva employs around 16,500 people in a highly complex, inefficient and completely overstaffed administration (EUSTAFOR 2020). The ambition to protect its large numbers of

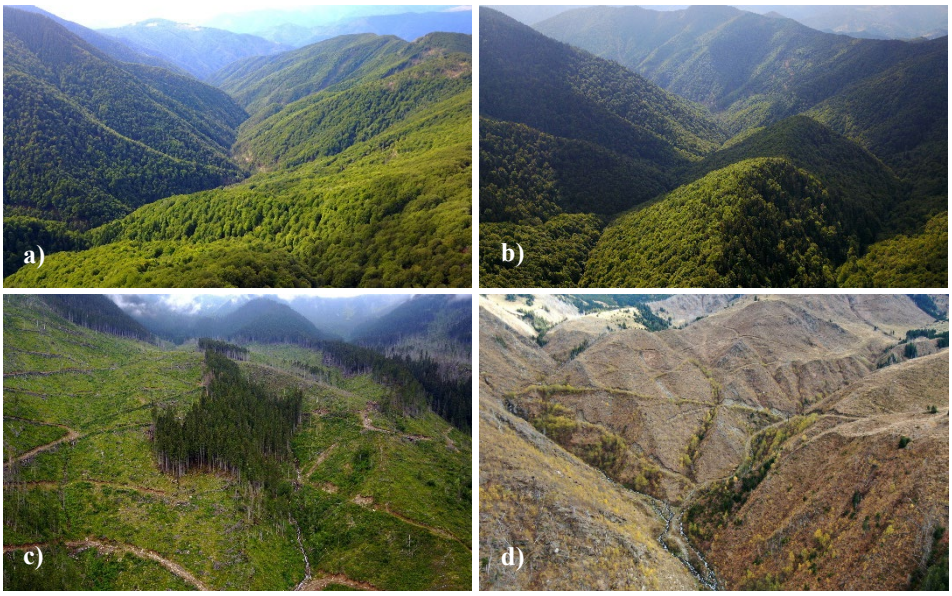

Fig. 7. a) and **b)** In the southern Carpathians there are still valleys difficult to acces and thus harbouring remains of virgin and old-growth mixed mountain forests. The use of drones is an important tool in research and indentification of locations. Valea Curpănului, Western Făgăraș mountains, 1200 to 1550 m a.s.l. **c)** and **d)** Large-sacale loggings of spruce dominated forests in the central southern Carpathians (Valea Rea, left; Groapele, Iezer-Păpușa, right), part of the Natura 2000 area Munții Făgăraș. 1250 to 2000 m a.s.l. (Photos: I. Holban, a) and b) 2017; c) and d) 06.11.2020).

Abb. 7. a) und **b)** In den südlichen Karpaten gibt es (noch) unzugängliche Tälder mit Vorkommen von Urwäldern und Naturwäldern (Buchen-Tannen-Fichten Bergmischwald). Dronen sind in diesen weglosen Gebieten ein wichtiges Hilfssmittel für Forschung und zur Kartierung von Urwäldern. Valea Curpănului, Westliches Făgăraș Gebirge, 1200–1550 m NN. **c)** und **d)** Großflächige Kahlhiebe vor allem der Fichtenbestände in den zentralen südlichen Karpaten (Valea Rea, links; Groapele, Iezer-Păpușa, rechts), Teilgebiete des Natura-2000-Gebietes Munții Făgăraș. 1250–2000 m NN (Fotos: I. Holban, a) and b) 2017; c) and d) 06.11.2020).

employees in rural areas and numerous other indirectly dependent jobs probably explains how Romsilva manages to maintain its operations largely unhindered from political directives. It funds all its activities (salaries, investments, infrastructure measures, support, advice, education and also "research") by own resources, and also transfers revenues to the state.

The implemented legislation in Romania demands that production forests have to be managed sustainably, and virgin forests are to be protected. Romanian forests are also subject to European law, such as the Habitats and Birds Directives. However, there is a severe lack of enforcement at all administration levels. For example, large-scale clear-cutting with more than three hectares is legally only allowed in exceptional situations (e.g., "sanitary cuttings" because of bark beetle calamities or security reasons). But in practice, large-scale clearcuts are the normal situation and declared as "allowed" shelterwood interventions. Extensive evidence proofs that such "legal", but also large-scale illegal logging takes place even in protected areas such as national parks, UNESCO World Heritage and Natura 2000 areas (LUICK 2021, LUICK et al. 2021a, b, c, KRUMM in ADZ 2022).

4. Conclusions

The Carpathian forests in Romania and also in Ukraine are some of the last remaining wildernesses of our temperate European forests. They are a precious archive of information, biodiversity, but also images and beauty. However, in Romania many virgin and quasi-virgin forests continuously disappeare. Mention the destruction of (ancient) forests, most people usually only associate it with images of the rain forests of the Amazon or Borneo; but similar destructions are also happening adjacent to our doorsteps. The virgin and old-growth forests of the Carpathians are highly relevant to us all. We in Europe share a global responsibility to protect our unique, irreplaceable natural heritage and must try to stop this practice whenever we can.

The failure of governance structures to stop illegal logging practises and to set in place sustainable forestry standards in Romania is only part of a larger truth. The overexploitation and continuing disappearance of Europe's unique natural heritage is due to a multitude of factors; Romania is both perpetrator and victim here. This includes competition-driven companies on the supply side in search of the cheapest possible raw materials, as well as processors and customers on the demand side for whom the price of a resource or product is a pivotal consideration. At a political level, various attempts such as infringement procedures of the EU against Romania have been made to address frauds and incompliances with European law but no concrete action was taken by the EU institutions yet. In 2017 the United Nations Environment Programme also warned that illegal logging in Romanian virgin forests was one of the "most significant threats to sustainability" facing European nature conservation. But even this dire warning failed to achieve anything (UNEP 2017). In the last five years the Ministry for Environment, Water and Forests has started actions against illegal logging, but insufficient and inefficient, while the Ministry of Economy wants to produce electricity from hydropower on the cost of the area of national parks.

Romania is a poor country with generally low wages and especially in the rural regions of the Carpathians. The forest is often the only reliable source of income for many municipalities and small private forest owners, as well as the basis for housing, heating and therefore basic survival. Enforcing protection requirements and demands by imposing bans and sovereign powers is not a sustainable strategy, because it does not create solidarity or encourage citizens to lend their support to protection and conservation strategies for the last remaining virgin forests. Such misplaced approaches will most likely be interpreted as arrogance from wealthy Western and Central European countries. For example, Germany has destroyed all its virgin forests since centuries, and we are still a long way from the targets of "2% wilderness" and "5% of Germany's forests to be permanently left to develop naturally on a legally binding basis" as formulated in the 2007 National Biodiversity Strategy. Specifically, we would call for the following:

(1) It is surely in the interests of Europe as a whole to conserve and protect the last remaining extensive virgin forests in Central Europe. The Carpathians play a central, irreplaceable role as an enclosed conservation landscape for European woodlands where the original populations of large carnivores can be protected.

(2) The EU has set ambitious targets in its new Biodiversity Strategy 2030, including the protection of virgin forests, and is urging the strict protection of all remaining virgin and old-growth forests (EU 2020). However, these goals cannot be met unless the Parliament and the European Commission work in parallel to adopt clear and detailed guidelines on implementation, coupled with a system of control mechanisms and sanctions for infringe-

ments. Attractive, reliable, long-term funding programmes (compensation for non-use), in turn, must accompany this. Private and municipal forest owners are perfectly entitled to demand financial compensation for the permanent non-utilisation of resources.

(3) We need creative ideas and concrete initiatives to integrate wilderness areas into regional value creation concepts. Simply limiting access to these impressive forests to a few specialists will not be enough. Financial resources must also be made available, and assistance given to our Romanian partners to aid implementation. Our efforts should focus on promoting genuinely sustainable projects that do not jeopardise the area's unique ecological qualities.

Erweiterte deutsche Zusammenfassung

Die naturnahen Wald- und Gebüschtypen Rumäniens und ihre Haupt-Gehölzarten – Der Aufsatz gibt einen Überblick über die Waldvegetation Rumäniens und ihre Nutz- und Schutzaspekte. Aufgrund einer großen Vielfalt an Klimazonen und Böden und einer langen postglazialen Vegetationsgeschichte sind die rumänischen Wälder sehr vielfältige und artenreiche Ökosysteme. Etwa 150 natürliche Waldökosysteme wurden in einer Vielzahl pflanzensoziologischer Arbeiten mit unterschiedlichen typologischen Ansätzen beschrieben, die als großklimatisch bedingte zonale Waldformationen sowie azonal auf Sonderstandorten vorkommen: (1) Waldsteppen und trockene Eichen-(*Quercus* spp.)-wälder; (2) Wälder mit Orient-Hainbuche (*Carpinus orientalis*); (3) Wälder mit Eichen (*Quercus* spp.) und Hainbuche (*Carpinus betulus*); (4) Wälder mit Buchen (*Fagus sylvatica*) und Buchen-Mischwälder; (5) Buchen-Tannen (*Abies alba*)-Fichten (*Picea abies*) Bergmischwälder; (6) Fichtenwälder; (7) Subalpines Buschland mit Latsche (*Pinus mugo* subsp. *mugo*). Auf Extremstandorten kommen azonale Wälder vor, dominiert von (8) Schwarzkiefer (*Pinus nigra* subsp. *banatica*); (9) Waldkiefer (*Pinus sylvestris*); (10) Karpaten-Lärche (*Larix decidua subsp. carpatica*) und Zirbelkiefer (*Pinus cembra*); (11) Edellaubholzarten, darunter Ahorn (*Acer* spp.), Esche (*Fraxinus* spp.), Ulme (*Ulmus* spp.), Linde (*Tilia* spp.); (12) Schwarzerle (*Alnus glutinosa*); (13) Grauerle (*Alnus incana*); (14) Deutscher Tamariske (*Myricaria germanica*); (15) Pionierwald aus Weiden (*Salix* spp.) und Pappeln (*Populus* spp.); (16) Wälder der Hartholzaue mit Eiche, Ulme (*Ulmus* spp.), Esche.

Herausragend ist die Fläche der etwa 100.000 bis 150.000 ha an Urwäldern im temperierten Klima. Hinzu kommen etwa 200.000 bis 300.000 ha Naturwälder, die in Rumänien als Quasi-Urwälder bezeichnet werden. Von diesen sind zwischen 2001 und 2019 etwa 350.000 ha infolge legaler und illegaler Holznutzung verschwunden. Dies sind Schätzwerte, denn eine Inventur von staatlicher Seite liegt bislang nicht vor. Damit ist dieses einzigartige Naturerbe Europas inzwischen hochgradig gefährdet. Von besonderer Bedeutung sind die Rot-Buchen(ur)wälder in vielfältigen standörtlichen Ausprägungen der südlichen Karpaten. Seit 2017 gehören 6 ausgewählte Urwälder in Rumänien zur UNESCO Weltkulturerbestätte "Alte Buchenwälder und Buchenurwälder der Karpaten und anderer Regionen Europas".

Zustand und Gefährdung und Urwäldern und Quasi-Urwäldern - Nach dem Forstgesetz wird auch in Rumänien eine nachhaltige Forstwirtschaft gefordert und Urwälder sind (theoretisch) geschützt. Zudem gilt auch das europäische Recht mit der FFH- und der EU-Vogelschutz-Richtlinie. Doch es mangelt auf allen Ebenen an der Durchsetzung. So wurde mit dem Forstgesetz von 2012 u. a. die Einrichtung eines Nationalen Katalogs der Urwälder und Quasi-Urwälder initiiert. Bis vor kurzem wurden alle Kartierungen und Studien zu Beiträgen für diesen Katalog über NGOs und durch freiwillig arbeitende Experten durchgeführt, oftmals sogar behindert durch staatliche Institutionen wie die staatliche Forstverwaltung (RomSilva). Erst im Jahr 2021 gab es erste kleinere Kartierungsaufträge seitens des rumänischen Umweltministeriums. Es wird sich zeigen, ob die Arbeiten im Jahr 2022 fortgesetzt werden (Status Februar 2022).

Auch in den 13 Nationalparken Rumäniens ist der Schutz der Urwälder und Quasi-Urwälder nicht gesichert. Nach den IUCN-Kriterien für die Schutzgebietskategorie Nationalpark sollten 75 % der Flächen als Kernzonen ohne Bewirtschaftung ausgewiesen sein. Dieser Zielwert wird von keinem

Nationalpark in Rumänien erreicht. In drei Nationalparken sind keine Kernzonen ausgewiesen, bzw. dazu existieren keine offiziellen Informationen. In sechs Nationalparken existieren nur sehr kleine Kerngebiete, nur in vier Nationalparken sind große Anteile als streng geschützte Kerngebiete ausgewiesen. Da vom Schutzstatus her nur Kernzonen frei von Nutzungen sind, ist es im rumänischen Rechtsverständnis legal, wenn in den Nationalparken Holz in großem Stil (auch im Großkahlhieb) eingeschlagen wird.

Es wurde durchaus versucht, die verheerenden großflächigen Kahlhiebe in bisher nicht geschützten Urwäldern und Naturwäldern und den Nationalparken auf EU-politischer Ebene zu thematisieren. Ein im Februar 2020 eingeleitetes Vertragsverletzungsverfahren der EU gegenüber Rumänien bleibt bisher jedoch folgenlos und wird seitens der EU systematisch verschleppt; konkretes Handeln durch die Gremien der EU ist mit Status Februar 2022 nicht feststellbar. Auch das Umweltprogramm der Vereinten Nationen warnte nach der Auswertung von Berichten und Satellitenaufnahmen bereits im November 2017, dass illegales Holzfällen in rumänischen Urwäldern eine der „bedeutendsten Bedrohungen für Nachhaltigkeit" im europäischen Naturschutz sei; doch auch diese Warnung blieb folgenlos (UNEP 2017).

Rumänien ist ein im europäischen Vergleich armes Land, und in den ländlichen Regionen sind Einnahmen aus dem Wald oft die einzigen verlässlichen Einkommensquellen für Kommunen und die ländliche Bevölkerung. Es ist daher auch keine nachhaltige Strategie, nur über Verbote und strenges hoheitliches Handeln Schutzanforderungen und -ansprüche durchzusetzen. Überhaupt ist Überheblichkeit aus einer reichen west- und mitteleuropäischen Sicht fehl am Platz. Der Komplex aus Holzindustrie, einer willigen Verwaltung, billigenden politischen Strukturen und den Lieferinteressen der Waldbesitzer kann sich in Ländern wie Rumänien nur durch eine globale Nachfrage mit wenig Skrupel und Moral entwickeln. Diese Waldzerstörung findet nicht in entfernten Waldregionen statt, sondern direkt „vor unserer Haustüre". Daraus folgt: (1) Es muss gesamteuropäisches Interesse sein, die letzten großflächigen europäischen Urwälder zu erhalten und zu schützen. (2) Von der Gemeinschaft der EU Länder, dem Parlament und der Europäischen Kommission müssen klare Richtlinien und deren Umsetzung in Verbindung mit attraktiven, sicheren und langfristig angelegten Förderprogrammen (Kompensationen für Nichtnutzung) geleistet werden. (3) Auf einer regionaler Ebene müssen neue kreative Ideen und konkrete Initiativen Wildnisgebiete in regionale Wertschöpfungskonzepte einbinden.

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Albert Reif wrote chapter 2 (45%), Rainer Luick wrote chapter 3 and 4 (25%), Erika Schneider, Adrian Oprea and Laszlo Rakosy contributed substantially with comments and corrections (10% each).

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Supplements

Supplement S1. Altitudinal zoning of the forests of the Southern Carpathians (after MAYER 1984, COLDEA 2004).

Beilage S1. Höhenstufenzonierung der Wälder der Südkarpaten (nach MAYER 1984, COLDEA 2004).

Supplement S2. Overview of the 13 national parks in Romania.

Beilage S2. Übersicht der 13 bestehenen Nationalparke in Rumänien.

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Supplement S1. Altitudinal zoning of the forests of the Southern Carpathians (after MAYER 1984, COLDEA 2004).

Beilage S1. Höhenstufenzonierung der Wälder der Südkarpaten (nach MAYER 1984, COLDEA 2004).

Altitude level	Zonal forests					Azonal forests and bushes	
		Tree species	Sea level (m AMSL)	Temperature [°C] (annual average)	Precipitation [mm] (annual average)	Stony and rocky soil	Floodplains
Upper subalpine	Dwarf pine shrubland	*Pinus mugo* subsp. *mugo*	1800–2300 1500–1600 Eastern Carpathians	0–2	1100–1225		Green alder (*Alnus viridis*) shrubland
Lower subalpine	Spruce forest: *Hieracio rotundati-Piceetum* , *Soldanello majoris-Piceetum* (base-poor) *Chrysanthemo rotundifolii-Piceetum* (medium to base-rich)	*Picea abies*	1300–1850 1200–1500 Eastern Carpathians	2–4	1100–1225	Larch (*Larix decidua* subsp. *carpatica*), stone pine (*Pinus cembra*) forest	Green alder (*Alnus viridis*) shrubland
Montane	Beech-fir-spruce mixed mountain forest: *Epipactido-Fagetum* (stony/rocky, rendzina, limestone) *Pulmonario rubrae-Fagetum* (fresh, base-rich to lime) *Dentario glandulosae-Fagetum, Symphyto cordati-Fagetum* *Festuco drymejae-Fagetum* (medium to base-poor) *Hieracio rotundati-Fagetum* (base-poor)	*Fagus sylvatica* , *Abies alba* , *Picea abies*	900–1500 700–1200 Eastern Carpathians	4–7	800–1200 (–1400)	Scots pine (*Pinus sylvestris*) forest: *Daphno blagayanae-Pinetum sylvestris* : Eastern Carpathians Black pine (*Pinus nigra* subsp. *banatica*) forest: Southern Carpathians	Tamarisk (*Myricaria germanica*) pioneer copses (*Salici-Myricarietum germanicae*) Grey alder (*Alnus incana*) alluvial forest (*Telekio speciosae-Alnetum*)
Submontane	Beech and mixed beech forest: *Galio schultesii-Fagetum* (base-rich) Oak/hornbeam forest: *Lathyro hallersteinii-Carpinetum* (moderately acidic)	*Fagus sylvatica* , *Carpinus betulus*	700–900	7–8	Approx. 800	*"Pino-Quercetum"* : *P. sylvestris, Quercus robur, Q. petraea* (Eastern Carpathians, siliceous)	Grey alder (*Alnus incana*) alluvial forest
Colline	Dacian oak and hornbeam forest alternating with Turkey oak/sessile oak forest	*Carpinus betulus, Quercus* spp., *Tilia tomentosa*	500–700	8–9	650–800	Dry grassland, transition to oak forest (*Quercus pubescens, Q. petraea*)	Black alder (*Alnus glutinosa*) alluvial forest with ash
Subcolline	Turkey/Hungarian oak forest (*Quercetum cerris-frainetto*), locally downy oak (*Q. pubescens*)	*Quercus cerris* , *Q . frainetto* , *Acer tataricum* , *Tilia tomentosa* , *Sorbus* spp.	100–500	9–10.5	500–650	(Dry grassland)	
Planar	Forest steppe	*Quercus* spp.	< 200	> 10.5	< 500	(Dry grassland, steppe)	Riparian hardwood forest: *Quercus robur, Fraxinus angustifolia* Softwood alluvial forest: *Salix alba* , *S . fragilis* , *Populus nigra*

Supplement S2. Overview of the 13 national parks in Romania (size, administration, management zoning and expert opinions on the degree of forestry interventions). CA (core area = strict protection zone), IPA (integral production area), SCA (sustainable conservation area), SDA (sustainable development area), FI (forestry interventions).

Beilage S2. Übersicht der 13 bestehenen Nationalparke in Rumänien (Größe, Verwaltung, Managementzonen und Experteneinschätzungen der forstlichen Eingriffsintensiäten). CA (Kernzone), IPA (Zone mit integrierter Produktion), SCA (Schutzzone mit nachhaltiger Nutzung), SDA (Zone mit nachhaltiger Entwicklung), FI (Einschätzung legaler und illegaler forstlicher Eingriffe / Nutzungen).

Name and webpage	Area (hectares)	Administration (NFA= National Forestry Administration)	Zonation according to management plans (if existing), and forestry interventions (legal and illegal) based on expert opinions ● minor ● high ● extreme				
			CA (ha)	IPA (ha)	SCA (ha)	SDA (ha)	FI
Munții Rodnei National Park (http://www.parcrodna.ro/)	47 202	NFA Romsilva	220 (strictly protected); 5 445 (scientific reserves)	26 369	14 558		●
Călimani National Park (http://www.calimani.ro/)	24 041	NFA Romsilva	744 (strictly protected); 384 (scientific reserves)	15 682	7 747		●
Cheile Bicazului Hășmaș National Park (http://www.cheilebicazului-hasmas.ro/)	6 794	NFA Romsilva	453	4 670	1 878	71	●
Ceahlău National Park (http://www.ceahlaupark.ro/)	7 743	Neamț County Council	371	5 009	2 130	233	●
Piatra Craiului National Park (http://www.pcrai.ro)	14 766	NFA Romsilva	6 291	104	7 034	1 336	●
Cozia National Park (https://cozia.ro/)	16 072 including 3 389 (2 subareas) UNESCO world heritage sites	NFA Romsilva	No information	8 134	7 894	44	●
National Park Buila-Vânturarița (http://www.buila.ro)	4 181	NFA Romsilva	No information	431	1 448		●
Defileul Jiului National Park (http://www.defileuljiului.ro/)	11 127	NFA Romsilva	No information	9 838	1 035	135	●
Retezat National Park (http://retezat.ro/)	38 138	NFA Romsilva	1 932 (strictly protected and scientific reserves)	20 863	15 337		●
Domogled-Valea Cernei National Park (http://www.domogled-cerna.ro/)	61 211 including 9 732 (3 subareas) UNESCO world heritage sites	NFA Romsilva	836	29 081	30 388	906	●
Semenic-Cheile Carașului National Park (http://pnscc.ro/)	36 051 including 4 677 UNESCO world heritage sites	NFA Romsilva	4 271	7 764	23 395	235	●
Cheile Nerei Beusnița National Park (https://www.cheilenereibeusnita.ro)	29 386 including 4 292 UNESCO world heritage sites	NFA Romsilva	4 271	9 676	15 406	19	●
Munții Măcin National Park (http://www.parcmacin.ro)	11 152	NFA Romsilva	449	3 418	7 273	12	●