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ORIGINAL PAPER

Virgin forests in Romania and Bulgaria: results of two national inventory projects and their implications for protection

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Abstract Despite extensive forest destruction in the Middle Ages and later intensive commercial forest management, remnants of virgin forests remained spared in some Central, Eastern and South-Eastern European countries. These virgin forests are the last examples of original forests in this part of Europe. That is why their protection becomes an important issue of current European forestry and nature protection policy. But the knowledge about the location and the area of virgin forests in these countries is incomplete up till now. This article has the prime goal to present a conceptual framework what virgin forests might be ("A conceptual framework for defining of virgin forests" section). Based on this framework, a working methodology has been tested in Bulgaria and Romania ("Results of the two national projects in Romania and in Bulgaria" section and further). For this reason two projects have been carried out by the Royal Dutch Society of Nature Conservation (KNNV) in close co-operation with the Forestry Institutes in Romania and in Bulgaria. The results of these projects are described in general terms and further analysis in the future is necessary to describe specific features like forest structure and spatial heterogeneity of these forests. Based on the results of the inventory, principles of sustainable protection and management of the mapped virgin forests were defined and described in the research reports. The usefulness of the inventory became evident already during the EU pre-accession period of both countries while preparing the NATURA 2000 network. The remaining virgin forests of temperate Europe are an inexhaustible source of ecological information about biodiversity, structure, natural processes and overall functioning of undisturbed forest ecosystems. Their research will reveal information which can be used for ecological restoration of man-made forests which are degraded through intensive forestry practices over the last centuries. The last virgin forests of temperate Europe

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represent an irreplaceable part of the natural capital of Europe and are worth to be protected by law. Their last remnants in South-Eastern and Eastern Europe are endangered by commercial activities. A full inventory of remaining virgin forests in all countries of temperate Europe is a matter of highest urgency. A representative selection of virgin forest sites should be declared by UNESCO as World Heritage Sites.

Keywords Forests · Virgin forests · Forest management · Forest protection · Nature protection · Natura 2000 network · Mapping habitats · Forest policy

Introduction

Temperate zone forests of Europe went through a very complicated history. Since ancient times, they were used for various purposes: fuel wood, pasture, timber extraction. Most contemporary man-made forests are plantations, monocultures which are a result of intensive commercial forestry. These activities were led mostly by economic interests with the application of various forms and methods of exploitation and technical manipulation. Although various nature-friendly management methods have been developed and applied within the organized forestry in the last 300 years, only a small portion of the European woodland area remained spared of human impact.

In the last few decades, the need for restoration and recurring measures for man-made forests became more and more obvious. It leads to application of principles of sustainability and multi-functionality in forest management (MCPFE 2002). The remaining virgin forests are the best source to understand the spontaneous processes that are essential for the functioning of woodlands as ecosystems. This scientific information can be applied in man-made forests to improve their species composition, health status and resistance towards various adverse factors with the aim to fulfill properly and in an integrated manner the economic, ecological and societal services. However, contrary to this urgent need, the information about the remaining virgin forests in temperate Europe is by far not complete.

Some countries of Central Europe performed inventories of their virgin forests already in the 1980s and 1990s, (e.g. Mlinšek et al. 1980; Průša 1985, 1990; Mayer 1986; Korpeľ 1995) and as a result of this work some forests were proclaimed as protected area. But a complete survey of remaining virgin forests in all the countries of temperate Europe is missing. Today, allocation and protection of virgin forests is a topic in the countries of South-Eastern and Eastern Europe following the changes in the early nineties because legal and illegal cutting is a problem for these forests.

During 2001–2005, two projects were conducted which are dealing with doing inventories and preparation of strategies for sustainable protection and management of virgin forests in Romania and Bulgaria. The projects were initiated by the Royal Dutch Society for Nature Conservation (KNNV) in the framework of a Dutch government programme for supporting countries in transition towards membership of EU and conservation of biodiversity (BBI-Matra Programme). They provided Bulgaria and Romania with information about the extent and the preservation status of their virgin forests and enabled them to categorize these forests as potential NATURA 2000 sites (both countries had to identify their potential NATURA 2000 sites by January 1, 2007 at the time of entering the EU). Moreover, the projects cover an important part of information related to recommendations of the MCPFE and the Convention on Biological Diversity (MCPFE 2002). The projects were carried out in close co-operation with the Forest research institutes in Romania and in Bulgaria. Within the KNNV, an expert group was involved by giving trainings and by coaching the project.

In this article we present a conceptual framework for defining virgin forests after giving first a short overview about virgin forests in general in Europe. Based on this conceptual framework criteria for selection and assessment of virgin forests were developed. These criteria were a starting point for the two national projects. The outcome of these projects is described in general terms. Their results are open to further detailed analysis at both national, regional and/or local level.

A short survey of forest history and history of virgin forests protection in temperate Europe

At the end and after the Middle Ages (fifteenth–seventeenth century), the area of forested land in Europe decreased drastically due to changes in land use patterns. Moreover, a more intensive exploitation of the remaining natural forests started and as a result of this the accessible forests were degraded by arbitrary cuttings (Küster 1998, 1999). In some countries, charcoal production for iron industry, shipbuilding and salt extraction led to full deforestation of large areas. In the beginning of the eighteenth century legal requirements came in force in some countries to avoid a wood-supply crisis and to improve the state of degraded forests (Von Carlowitz 1713). At that time forest management concentrated mainly on artificial regeneration of deteriorated woodlands, in most cases by fast growing conifers. Also degraded agricultural land was planted with trees for timber and wood production (Fanta 2005).

In the first half of the nineteenth century some enlightened forest owners developed the idea to protect some last remnants of virgin forests by omitting human intervention. This was seen as a principle of saving untouched (forest) wild nature. The first three virgin forest reserves of temperate Europe were established in South Bohemia, Czech Republic: Žofín and Hojná Voda, both in the Novohradské hory Mountains which were established in 1838; and Boubín, Šumava Mountains which was established in 1858 (Průša 1985, 1990). All these sites exist till today as nature reserves and as examples of undisturbed natural forest ecosystems (mixed Beech-Norway spruce-Silver fir forests). They are a subject for systematic monitoring and used for research of natural development processes (Vrška et al. 2001).

Later on, also in other European countries these examples were followed. As a result of all these activities, a network of protected forests exists throughout Europe, which includes forests of various state of naturalness: from really undisturbed virgin forests till various types of ancient woodlands which were once used by man in various ways (e.g. in the Middle Ages), but later left to natural development without any new human intervention (Bücking et al. 2000; Vrška et al. 2002, 2006, 2009; Meyer et al. 2006). Today, these sites are important objects for scientific research in order to obtain information over natural structures and processes, which can be used to restore and to rehabilitate intensively used, man-made forests (Koop and Hilgen 1987; Schuck et al. 1994; Pontailler et al. 1997; Parviainen et al. 2000; Drößler and Von Lüpke 2005; Von Oheimb et al. 2005).

A conceptual framework for defining of virgin forests

A unifying concept

In the literature, a broad range of terms has been used to describe the specific characteristics of non-intervention forests by man (see e.g. Brünig and Mayer 1980; Schuck et al.

1994; Parviainen 2005). The terms vary from natural, near- and semi-natural, undisturbed, etc. to virgin, pristine and primeval forests, mainly to emphasize "the natural conditions" as a result of full absence of human intervention. In the United Kingdom, the term ancient woodlands is reserved for forests which are old and which developed spontaneously over centuries, but the influence of man in the past is still visible in their composition and/or structural features (e.g. Peterken 1993, 1996; Schuck et al. 1994). In some cases the term old-growth forests is used to identify forests in question (Wirth et al. 2009). But in the United States this term is also used for forests, where old trees can be removed, although the original composition or physiognomy of these forests is still present (Gilg 2005).

In our approach, we propose to use the term virgin forest as a unifying concept for forests which are not influenced directly by man in their development. The species composition (connected with the biogeographical zone), structure and dynamic processes are important features for the identification of this type of forests compared to intensively managed forests. Also the minimum area must be taken into consideration. Based on these features, we developed the following definition:

Species composition (in relation to biogeography)

"Virgin forests are formed by site-indigenous tree species, native to the biogeographical region and phytogeographic zone. They form specific forest types with their characteristic species composition, corresponding spatial structures, dynamics and overall diversity (including genetic diversity) forthcoming from their postglacial history and ecological relations with their abiotic environment (position above sea level and topography, macroclimate, and nutrient and water availability)."

Structure

"In virgin forests tree and shrub species are present in various stages of their life cycle (seedlings, young growth, advanced growth, mature and old growth) and as dead wood (standing and lying on the ground) in various stages of decay. Their vertical and horizontal structures may vary from complex to irregular, depending on forest type, disturbance regimes and natural development dynamics. A typical structural feature of virgin forests is the presence of very old and very thick trees."

Dynamics

"The dynamics of virgin forests are connected to ecological properties of dominant tree species, site factors and disturbance regimes forthcoming from the abiotic and biotic environment (hurricanes, snow, flooding, insect plagues, etc.). The complex effect of these driving forces leads to small or large scale differentiation of natural regeneration, development and decay of tree growth. It also may lead to development of temporary tree-less stages in the course of forest succession (dominated e.g. by herbs or grasses). Spontaneous dynamics enable the forest community to exist continuously and in all of its forms, and without limit in time."

Minimum area

"Not every small forest fragment not influenced by man may be seen as a virgin forest. Next to time, spontaneous development of a forest also needs space. A minimum area is an

area wherein all succession stages of a forest community can develop under conditions usual in the development of the given forest type. Hence, the minimum area depends strongly on particular forest types and their potential disturbance regimes."

Based on this conceptual framework a set of criteria for implementation in the two national projects was worked out. We describe this set here in headlines and further information can be obtained from the project reports which are available on website www.veenecology.nl.

How to identify virgin forests in the field

In the preparation phase of the two projects, each country was divided in several regions. Each region was allotted to a working team consisting of specialists from various fields of science (e.g. forest ecologist, botanist, zoologist, soil scientist) which worked under the supervision of an experienced senior researcher.

Identification of virgin forests was based on:

- historical evidence;
- structural features of the forests.

In both countries, historical evidence was documented in regional archives, historical maps, management plans, previous research studies and other written documents. Most indications came from the forest evidence data as they have been recorded during the routine forest inventories and included in forest management plans of particular management units. More exact information of local foresters was also recorded by means of interviews. The teams used written documentation and maps of the area, and carried out literature studies to make lists of species and to consider their biogeographic and protection status (e.g. rare, relict and/or endemic species). They also collected available historical and palynological information. Available remote sensing maps were used, especially to identify the boundaries of virgin forest complexes. During the fieldwork, the teams performed detailed descriptions and made basic measurements in transects to record various types of virgin forests.

Structural features (homogeneity or diversity in species composition, age and dimensions) provide good characteristics of various development stages of the forests. Projected and interpreted over time as development stages and phases, they make it possible to judge the development processes and the character of natural disturbances, which influenced the development of the forests in the past.

Authors as Leibundgut (1978) and Mayer (1986) distinguished various development stages in virgin forests and proposed various schemes which characterizes their development cycle. Based on extensive research in Slovak virgin forests, Korpeľ (1995) developed a scheme, which is primarily related to the disturbance and/or decay of the growth as the driving force behind the change of overall spatial structure of a virgin forest. He distinguished various phases within his three development stages, based on how slow or how fast the decay process is. His approach can be seen as a basic assumption for the evaluation of structural features of virgin forests in the temperate zone of Europe.

Based on this approach, Biriş et al. (2000) proposed a set of criteria for the selection of virgin forests which are used in both projects:

1. Authenticity
   - Presence of native, site-indigenous species;
   - Absence of elements showing human influence in the past (like stumps, skidding, roads, effects of cattle grazing); no features of artificial discontinuity;

- Virgin forest site is representative of one or more forest formations in the area;
- No external factors causing risk for continuation of spontaneous development.

2. Structural features
   - Spatial (vertical and horizontal) differentiation of growth related to development stages and phases;
   - Occurrence of dead wood (standing and laying on the ground), in different stages of decay.
3. Diversity in ages and dimensions
   - Presence of a broad range of tree dimensions and ages both at the local stand level and the tree species level;
   - Occurrence of very old and large trees.
4. Minimum area (size)
   A continuous development of virgin forest is possible only in an area large enough to sustain all processes inherent to the forest formation in question. Potential natural disturbance regimes must be taken into consideration. That is why the minimum area might be different in various types of virgin forests. For practical inventory reasons, an area of 50 ha was taken as the minimum area enabling sustainable development of the site and its effective protection.
5. Natural boundaries
   Virgin forest boundaries are preferably natural topographic phenomena like rivers and small water streams, mountain ridges and natural borders of relief forms.

How to identify individual virgin forest sites?

Identification of potential individual virgin forest complexes/sites was based on combination of:

- historical and written documentation,
- study of aerial photographs and satellite images,
- field visits and fieldwork.

The most important part of the identification process was the field visit to individual forest sites put forward as potential virgin forests. During the fieldwork the proposed sites were described using quantitative parameters as much as possible. A combination of these parameters makes it possible to gain insight into the long-term development of the forest complexes. The following data were recorded:

- Authenticity (species composition; spatial, age and dimension structures; presence of dead wood);
- Area (size);
- Character of boundaries;
- Representativeness of the forest complex for local conditions;
- Biological and ecological diversity (number of plant and animal species; number of endemic, relict and rare species; number of microhabitats);
- Number of protected and threatened plant and animal species (according to the IUCN classification, Habitat Directive, Bern Convention, Bonn Convention, National Red lists);

– Absence of obvious threats for continuous forest development and biodiversity;
– Forest history and continuity in development;
– Potential use for scientific research;
– Environmental education function;
– Accessibility of the location as a potential threat;
– Existence or absence of buffer and transition zones around the area.

All these data were stored in a GIS database to make further analyses of these forest complexes possible for protection and sustainable management reasons, identification of sites within the Pan-European Ecological Network and within NATURA 2000 networks and for special protection reasons like minimizing spatial isolation impacts and development of networks with adjacent virgin forest complexes.

Results of the two national projects in Romania and in Bulgaria

History of forests in Romania and Bulgaria

Romania

Due to the variety of climatic conditions and altitude above sea level, Romania is the most varied country for vegetation and forest growth in temperate Europe. The conditions vary from the East-Mediterranean (Black Sea) till Continental climates and from lowland floodplain and coastal sites till high mountains with forest and shrub formations along and above the timberline in the Central and Southern Carpathians.

At the beginning of the Neolithic period (some 8,000 years B.P.), forests covered ca. 80% of the present day Romanian territory (Biriş et al. 2006). Three historical periods of massive forest cuttings are known: the Dacian Kingdom and its succession (100 BC–105 AD); the Ottoman Empire (thirteenth to nineteenth century); and the Inter-bellum (first half of the twentieth century).

By the end of the nineteenth century, only 40% of the country was covered by forests. This means that 50% of the forested area was removed and changed mostly into agricultural land. In 1940, forests were reduced till 28% of the country area. Since that time, the total cover of forests remained more or less stable (today 27%).

According to recent forest inventories data, broadleaved tree species cover 70.1%, while conifers 29.9%. The most widespread species are *Fagus sylvatica* (31,5%), *Picea abies* (22%) and *Quercus* sp. (18%).

The first official forest protection measure was taken in the fourteenth century, by means of the "Carti de paduri oprite" (Letters of forbidden forests). The letter mentions "braniştı," which means forests in which nobody had the right to cut trees, mow hay or graze cattle; also hunting, fishing or picking fruits was forbidden. These areas may be seen as the first precursors of later forest reserves.

Regular forest protection started first in the Banat region in the eighteenth century (1739). In Transylvania, a law on forest use was published in 1781. Similar regulations followed later in other parts of the country (Bucovina 1786; Moldavia 1792; Wallachia 1793). In the nineteenth century, however, the Treaty of Adrianople (1829) had a new, strongly negative impact on lowland forests. Between 1856 an 1890 some 3 million hectares of remaining forests were changed into arable land to cultivate cereals. In the Inter-bellum period, the forest area was further reduced by 1.3 million hectares.

In the 1930s, under the influence of then modern Central European forestry ideas, the old practice of unscrupulous forest exploitation was stopped. Further reduction of the forested area was forbidden and forestry planning was introduced. Within this development, one of the most important tasks of leading foresters of that time was the exploitation of virgin forests and introduction of organized forestry. Only some mountain forests were allotted for a soil protection function and/or avalanche control. Within these efforts, the first virgin forest reserve in Romania, the Slătioara forest reserve in the Bistriţa Mts., was established by the forester F. Cech in 1934.

The above described changes in the area of Romanian forests and their use could not remain without impact on existing virgin forests. The following data illustrate the decline of their area:

- ca. 2 million hectares of virgin forests at the end of the nineteenth century
- 700,000 hectares in 1945
- 400,000 hectares in 1984 (forest inventory data)
- 218,000 hectares in 2004 (recent virgin forest inventory).

In the 1990s, virgin forests became a matter of protection within the national nature protection policy. Today, a total of 800.000 ha of forests of various degree of naturalness and protection status (including the virgin forests sites of the recent inventory) are included in the system of protected areas (nature reserves, national parks and landscape protected areas). These protected forests represent ca. 12.5% of the total forested area of the country.

A description of some selected virgin forests in Romania was published recently by Giurgiu et al. (2001)

Bulgaria

Bulgaria is also a country with a great variation in natural conditions, reaching from the East-Mediterranean coast and steppes to the highest elevations of the Balkan mountain ranges. Broadleaved forests prevail with 68.9% above conifers with 31.1%. The most widespread tree species are *Quercus* sp. (32.6%) and *Fagus* (16.1%), followed by *Pinus sylvestris* (16.0%) and *P. nigra* (8.5%). Some 80% of forests are owned by the state; the remaining 20% are in private or communal hands.

Forests were used for various purposes since immemorial time. Large areas of forests were cut for timber and supply fuel for big cities from the middle ages until the nineteenth century. Lowland and upland forests were then mostly converted into agricultural land (arable land, pastures). When left abandoned, spontaneous development resulted in some cases into very interesting ancient/semi-virgin forests (e.g. *Pinus nigra* forest in the Slavyanka Mountains). The first Bulgarian Forest Act was adopted in 1883, and in 1901 a systematic forest inventory was started, producing basic data about the forest area of the country to be used for forestry planning.

The first forest reserves were established in 1933, including remnants of valuable natural forests in various parts of the country. In 1934, the first national park in the Vitosha Mts. was proclaimed, involving virgin forests of the area.

A strong impetus for extension of protected forests and further nature reserves was provided by adoption of the Nature Protection Act in 1967. Later, in the first half of the 1990s, three large protected areas were established:

- the Central Balkan National Park (1991, nearly 72,000 ha);
- the Rila National Park (1992, 108,000 ha); and
- the Strandzha Nature Park (1995, more than 116,000 ha).

All of these large protected areas include relatively extensive virgin forests. Because of differences among these areas, their virgin forests represent many of the local and regional indigenous forest communities.

Today, the area under protection covers 578,000 ha, which represents 5.2% of the country area. From the forested area, 16.5% is under various forms of protection (Raev 2004; Raev and Dimitrov 2004; Veen and Raev 2006).

Description of some results from the national inventories

Outcome of mapping activities

Based on the above described parameters, the following results were achieved:

- in Romania: 3,402 sites > 50 ha with a total area: total 218,494 ha
- in Bulgaria: 160 sites > 50 ha with a total area: total 103,356 ha.

In both countries, the identified virgin forests sites are mainly located in the mountain regions of both countries. In the lowland areas, the presence of virgin forests is limited to some floodplain forests along the large rivers, in the Danube Delta and along the Black Sea coast (Figs. 1, 2).

Some sites smaller than 50 ha were also visited within the identification process, but, with respect to the "minimum area" criterion, were not placed on the list of sites. The potential number of virgin forest sites smaller than 50 ha might be high in both countries (and especially in Romania), but will probably not influence the total area of virgin forests in a significant way.

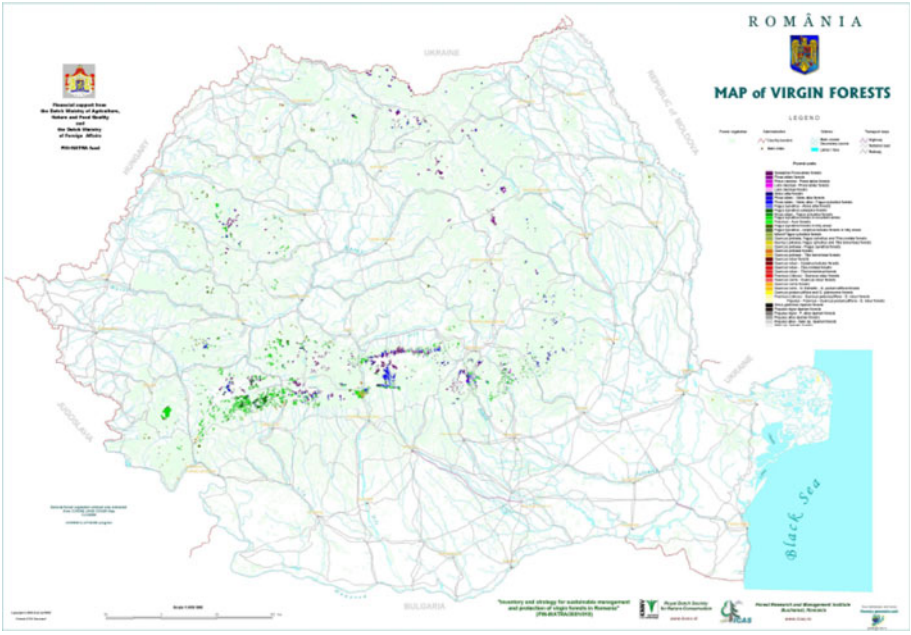

Fig. 1 Distribution of mapped virgin forests in Romania (*Source*: Biriş and Veen 2005)

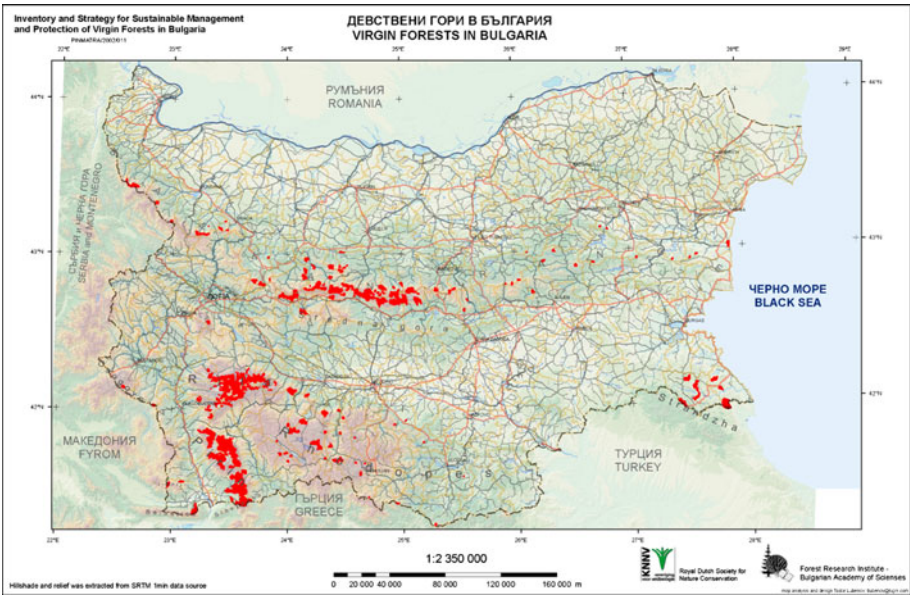

Fig. 2 Distribution of mapped virgin forests in Bulgaria (*Source*: Veen and Raev 2006)

Distribution over different woodland types

Based on the dominant tree species, six well-defined virgin forest types and one "undefined/other" mixed type were identified (Fig. 3). The *Fagus sylvatica,* and in Bulgaria also *Fagus orientalis,* forest is the prevailing forest type in both countries. In Romania it represents 58% of all virgin forests in the country. Here, extensive European beech forests are present mostly in the Banat Region, including the Nera Nature Reserve with a coherent virgin forest complex which covers 6,260 ha in altitudes between 700 and 1350 m a.s.l. This forest has been repeatedly studied by Romanian experts (Smejkal et al. 1995; Turcu and Şteţca 2006). Also *Fagus sylvatica* represents the most common forest formation in the Balkan Range (Stara Planina) in Bulgaria. It forms a continuous belt of forests at altitudes reaching from 800–1,000 m to 1,500–1,600 m a.s.l. In some locations it also descends to lower altitudes. *Fagus orientalis* forests have a limited distribution. They prefer shady and humid sites, especially on locations where climatic inversions occur.

The coniferous virgin forests dominated by *Picea abies, Abies alba, Pinus cembra* and *Larix decidua* are important virgin forest types in Romanian high mountains. The same is true also for Bulgaria, with the difference that also *Pinus sylvestris, P. peuce, P. nigra, P. leucodermis* and *P. mugo* cover extensive areas. It is necessary to mention that *Pinus mugo* habitats (totally some 50,000 ha) were not included in the inventory project in Romania; they are classified as "subalpine mountain pine scrub", not as forests. This explains why coniferous forests are more common than beech forests in the Bulgarian survey. *Pinus peuce and P. leucodermis* are very specific virgin forest types on higher altitudes in Bulgaria.

The lower altitude forests of hills, plateaus and plains with *Quercus petraea* and *Q. robur* as dominant species are rare in both countries. Only small remnants of the former extensive lowland forests remain spared in isolated locations.

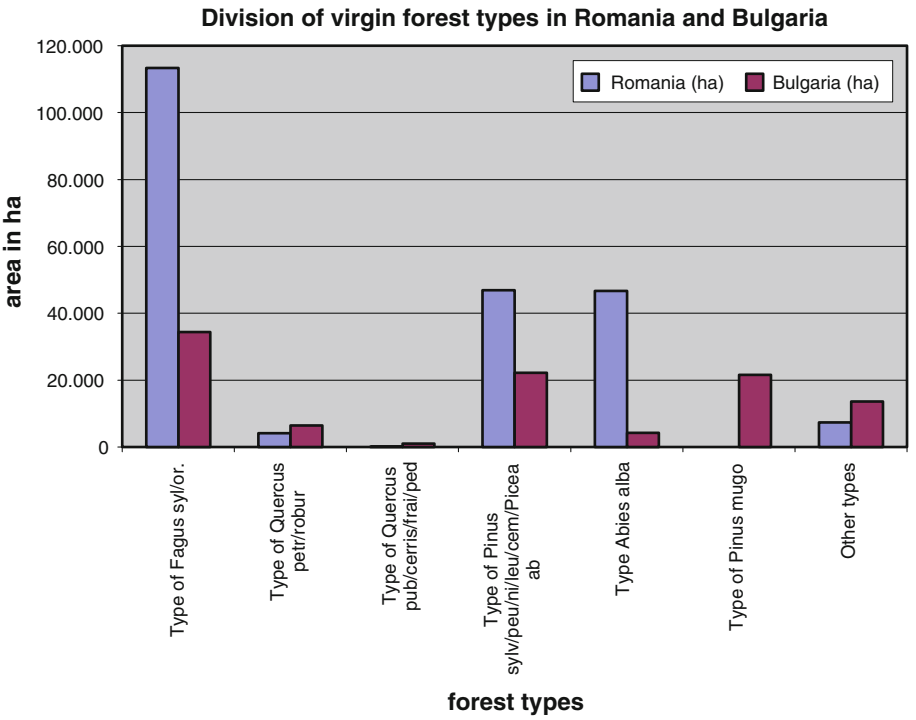

Fig. 3 Distribution of virgin forests over forest types in Romania and Bulgaria (*Sources*: Biriş and Veen 2005; Veen and Raev 2006)

Virgin forests dominated by *Quercus pubescens, Q. frainetto* and *Q. cerris* are also rare and typical for xero-thermic locations, such as southern slopes in lower areas in both countries.

The last category of our survey involves riparian forests dominated by various tree species (*Salix* sp., *Populus* sp., *Fraxinus angustifolia, Ulmus minor, U. laevis)* related to locally different flooding regimes. One assessed site with a virgin forest of *Tilio-Acerion* type is also included here.

Distribution over altitudinal zones

The distribution of virgin forests over altitudes above sea level is given in Figs. 4 and 5. Differences between the countries are significant.

In Bulgaria, 51% of virgin forests are located at altitudes above 1,400 m a.s.l. In Romania only 15.5% of virgin forests were located at these altitudes. However it must be taken into account that *Pinus mugo* forests were not included in this country. Nevertheless, the (high) mountain forest formations, typical of ranges between 1,300 and 2,200 m a.s.l. are well developed and better preserved in Bulgaria.

The ranges between 600–1,000 and 1,000–1,400 m a.s.l. are the most important altitudinal zones for the occurrence of Romanian virgin forests. About 77% of virgin forests are situated at these altitudes. In Bulgaria only 38% of virgin forests are found at these altitudinal zones. This means that *Fagus*-dominated virgin forests (in lower altitudes in

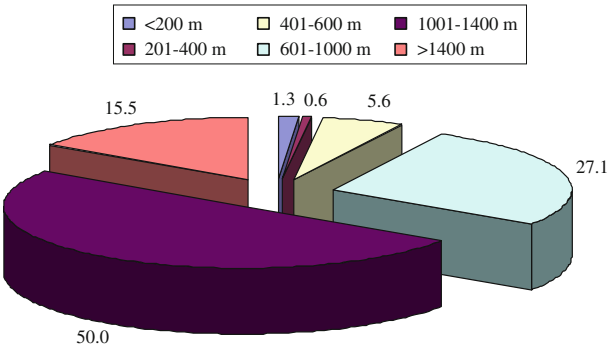

Fig. 4 Distribution of virgin forests in Romania over altitudinal zones (*Source*: Biriş and Veen 2005)

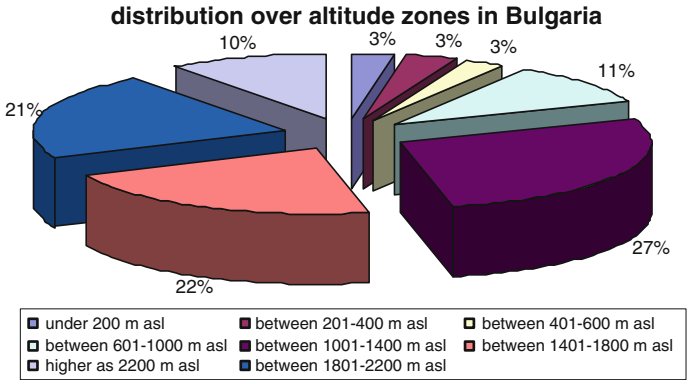

Fig. 5 Distribution of virgin forests in Bulgaria over altitudinal zones (*Source*: Veen and Raev 2006)

mixture with *Quercus petraea;* in higher altitudes mixed with *Abies alba* and/or *Picea abies*) are the more common and better preserved forest types in Romania. This fact probably has to do with the topographical conditions of the Romanian Carpathians—remote inaccessible valleys and steep slopes which did not allow for access and regular forest operations in the past.

Lowland forests below 600 m a.s.l. are rare in both countries and their share is less than 5% of the recorded virgin forest area. It is clear that forests at these altitudes were subjected to heavy exploitation in the past and mostly converted into agricultural land. The remaining forests have been intensively used until recently because of their high valuable timber production.

Distribution over slope categories

As figured out in Fig. 6a, b, 68% of the Romanian virgin forests are situated on slopes between 30 and 40 degrees; this is only 19% in Bulgaria. It is the opposite for slopes between 15 and 30 degrees: 24% in Romania, 55% in Bulgaria. This difference is related to the topography of the Carpathian mountain ranges and their inaccessibility. It also means that virgin forests in Romania are more connected with exposition through factors

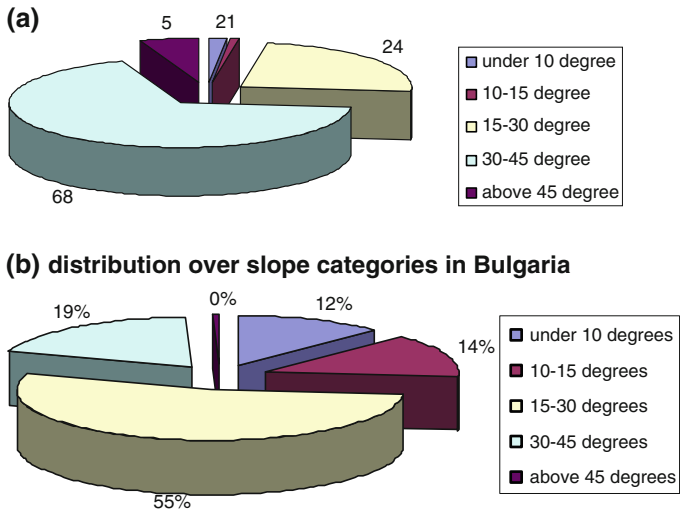

Fig. 6 **a** Distribution of virgin forests in Romania over slope categories (*Source*: Biriş and Veen 2005) **b** Distribution of virgin forests in Bugaria over slope categories (*Source*: Veen and Raev 2006)

such as sun or wind, and to edaphic conditions and water runoff. Another possible explanation is that Romanian forests located on slopes over 35 degrees have been protected by law because of soil erosion, water runoff control and/or other risks. Due to these regulations, exploitation of these forests was limited or completely abandoned.

Fragmentation of virgin forest complexes

Apart from the different area of virgin forests recorded in both countries, the statistics reveal a quite different spatial distribution and configuration of virgin forest remnants (see Figs. 1, 2, 4 and 5):

- an extreme fragmentation of virgin forest sites in Romania: the distribution of area classes is extremely uni-modal—2,600 sites (90%) have an area smaller than 100 ha; 600 sites belong to the area class 101–500 ha; larger areas are rare, the largest virgin forest site is the already mentioned Nera nature reserve, 6,260 ha;
- lower total number of sites in Bulgaria, but many of them in larger area classes; the two largest virgin forest sites identified in Bulgaria form part of the reserves Steneto (3,594 ha) and Djendema (4,213 ha), both in the Balkan Range Mountains (Stara Planina).

Conclusions and recommendations

The inventory procedure applied in Romania and Bulgaria supplied both countries with a reliable survey about the area and allocation of their remaining virgin forests. The maps and GIS databases are valuable and in fact indispensable contribution for the development of national networks of protected areas. Within the EU accession procedure, in Bulgaria more than 97%, and in Romania more than 80%, of the area of recorded virgin forest sites

were included in the NATURA 2000 networks. Their protection and survival are assured for the future.

The different spatial distributions of virgin forest complexes in Romania and Bulgaria indicate a need for different nature protection policies in these two countries. In Bulgaria, the focus should be put on management and protection of large protected areas (national and nature parks) with virgin forests as the main component of the protected nature. The fragmented situation in Romania should provide, in the first place, an impetus to establish a network of functional bio-corridors between adjacent virgin forest sites and to design large enough buffer zones to protect the isolated fragments against possible negative impact from the surroundings to avoid genetic erosion of isolated populations.

The inventory brought basic data about the variability of biodiversity of forests not influenced by past human activities. These data form a baseline for future monitoring and research. Possible research themes are numerous; they reach from investigation of structures and natural processes to studies in ecosystem processes and biodiversity development in various stages of succession. Also, research on various disturbance regimes in relation to the minimum area in various types of virgin forest types should be conducted. All this scientific information will be of high importance for protection of indentified virgin forest complexes and sites.

The method used for identification and inventory of virgin forests in Romania and Bulgaria proved to be applicable in various virgin forest types and under very different natural conditions. The achieved results give an impetus to start similar inventory programs in all countries, to come to a complete survey of remaining virgin forests in whole temperate Europe. It seems that temperate Europe hides more virgin forests than assumptions until now anticipate. We propose to start an EU inventory programme to come to a survey of all remaining virgin forests of temperate Europe. Countries to be investigated are Ukraine, Belarus, Turkey, countries of the Balkan Peninsula and the European part of Russia.

Virgin forests of temperate Europe are remnants of nature pure sang. Declaration of a representative selection of virgin forests of temperate Europe as World Heritage Sites will be an act of high cultural importance.

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