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Diversity and primary productivity of hill beech forests from Doftana Valley (Romanian Subcarpathians)

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Abstract. The hill beech forests cover most of the woody area in the Doftana Valley. The present study refers, for the first time, to two beech forests typical to this belt, which belong to the phytocoenological associations *Epipactieto-Fagetum* (Resmeriță, 1972), in the Lunca Mare area, and *Hieracio rotundati-Fagetum* (Vida 1983, Täuber 1987) in the Şotrile area, from floristic, structural, biomass and necromass accumulation point of view, within the framework of the vertical structure of biocoenosis. The limestone substratum, occasionally with small outcrops in the first beech forest, differs chiefly through the pH levels (6.34-5.67) from the siliceous substratum (pH 5.11-4.36) in the second beech forest. The layer of trees is dominated by *Fagus sylvatica* in both forests; this species is associated with *Cerasus avium* (4.5%), *Acer pseudoplatanus* (2%) and *Sorbus torminalis* (2%) in the first beech forest, and is monodominant in the second. Although the forest underwent selective cuts, more intense in the Lunca Mare area, the aboveground ligneous biomass reaches nowadays 222 t/ha in the Lunca Mare area compared to only 163 t/ha in the Şotrile area; the average height is 28.8±2.49 m and 23.7±1.12 m, respectively, and the diameter is 33.30±7.9 cm and 31.60±6.28 cm, respectively. The species of macrofungi, not very numerous during the study because of scarce precipitations (6 and 7 species, respectively), are predominant on the rhytidoma trees in the beech forest rooted on the limestone ground; in the Şotrile beech forest they are joined by mycorrhizal and parasite species. The layer of shrub is underdeveloped. The herbaceous layer is discontinuous, and includes, along herbs, small plants and saplings belonging to the ligneous species and to liana *Hedera helix*. The maximal value of the aboveground biomass of the layer is 317 kg/ha DM in the Lunca Mare area and 235 kg /ha DM in the Şotrile area. Bryophyta is present in large quantities, especially in the Şotrile area, where by May it represents up to 20% of the inferior layer's biomass; on the limestone ground they do not exceed 0.5%. The most frequent are on the soil surface: *Polytrichum formosum, Pogonatum nanum, Hypnum cupressiforme, Tortella tortuosa* at Şotrile and, respectively *Metzgeria furcata* var. *ulvula, Leskea nervosa , Ctenidium molluscum* at Lunca Mare. In the Lunca Mare area, the most relevant herbaceous species in the structure of the biomass are *Viola reichenbachiana, Festuca drymeja, Sanicula europaea* and *Campanula trachelium*; in spring there are also *Erytronium dens-canis* and *Lathyrus vernus*. In the Şotrile area these are: *Luzula luzuloides, Carex digitata, Calamagrostis arundinacea* and *Hieracium transsylvanicum*, in both spring and autumn. *Hedera helix*, present especially at the surface, is the most frequent and best represented in terms of biomass in both beech forests, and in particular in the Lunca Mare site.

The species characteristic to the phytocoenological association and to the alliances where these beech forests are included are representative through their biomass for the *Hieracio rotundati-Fagetum* association, while the orchids species characteristic to associations present on the limestone ground, although very diverse and with a great number of individuals for this taxonomic group, are not representative, neither as frequency nor as biomass or density, compared to other herbal species with a larger coenotic value, which are included in the *Epipactieto-Fagetum* association. The necromass accumulated in the area analyzed decays slowly, varying greatly with surface and time. It averages 4492 kg/ha in the Lunca Mare area and 4134 kg/ha in the Șotrile area. The necromass is made mostly of fallen leaves, and, at least in the Lunca Mare area, the July values are amplified by vernal herb flora.
Keywords: *Fagus sylvatica* forest, plant diversity, trees, herbs, orchids, mosses, fungi, aboveground biomass

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Introduction

The mountain and hill beech forests, dominant or mixed with other deciduous species or with coniferous species, are the most widespread forests in Romania, accounting for about 30% of the total current forest area.

In Valea Doftanei, tributary of the Prahova River, a study of the ecosystems shows that beech forests are predominant, covering up to 80% of the forest area (Paucă-Comănescu unpublished data). Their diversity is high, both as mixture of tree species (oak-beech forests, dominant hill and mountain beech forests, mixtures of beech and fir trees, monodominant high altitude beech forests) and as association with different herbaceous species.

Most of the forests are mature, aged over 150-180 years. During only the past of 10-15 years massive cuts have been performed in the mountain beech forests and in the fir-beech forests, in stands with very old trees. Only one area of mountain beech forests and fir-beech forests was preserved, becoming a protected area at the national and European level, included in the European network Natura 2000 as ROSCI 0153 - Glodeasa Forest.

Vegetation and ecological research on this valley is very scarce and rather recent. The first botanical note on this area (Dihoru et al. 1969) concerns the flora and vegetation of Secăria-Florei area only, now disappeared under the Paltinul accumulation lake. More recently, research on the biodiversity of the oak and oak-beech forests from Doftana Valley near Câmpina city (Oromulu et al. 2007, 2008) and on the biocoenotical structure of alluvial shrubs close to Lunca Mare village (Paucă-Comănescu et al. 2008) were published.

The present paper refers, from a botanical perspective, to several beech forest types located on the right bank of the Doftana River, downstream of Paltinul dam. It focuses namely on the diversity of the existing flora (vascular plants, macrofungi, bryophytes), on the structure of biocoenoses dominated by beech, and on the biomass of primary producers.

Materials and methods

Study area

The two beech forests studied are located in the Doftana Valley (Teleajen Subcarpathians, included in Curvature Subcarpathians), close to Lunca Mare (LM) village (N 45^{0}10'34"; E 25^{0}45'18,0") and at the onset of the road to Șotrile (SO) village (N 45^{0}13'39,3"; E 25^{0}43'41,9"); they are located close to each other on the mountainside above the river (cca.1 km). The forests form a massive continuum, and their age is about 100 years on both sites.

The bedrock belongs to the conglomerates, and include in their sandstone matrix a wide petrographic variation, a function of the strictly spatial position: quartzite, mica-schists, amphibolites, gneisses, and also sandy Senonian limestone and cleft with calcite. Because of this wide diversity, the subsoil of the two beech forests, although close one to another, is quite different.

Climatically, the area is temperate-continental, with limited valley influences. The multiannual average temperature (Câmpina weather station) is 9^{0}C and the annual rainfall is 850 mm (Armaş, 1999).

The local characteristics of the two sites, Lunca Mare (LM) and Şotrile (SO), are presented in Table 1. We notice because of a 100 m altitude difference (the Şotrile site being located upstream on Doftana River) and its north-north east orientation of the slope there is an amplification of the thermal differences between their local microclimate.

Methods

The sample areas were distributed randomly over one hectare, and the measurements were done specifically, by layer, within the vertical architecture of each forest phytocoenosis. The tree layer was inventoried on 500 m^2 circular areas, with the centers placed randomly in different locations, paying attention not to overlap the circumferences. Trunk diameters (calculated as the trunk circumference measured with graded tape at 1.30 m height) and height (using a Bitterlich relascope) of all the trees were measured. The shrub layer and the seedlings were inventoried on the same areas as the big trees.

The herbaceous layer was inventoried on circular areas of 0.25 m^2, delimited by a metallic frame, in 100 repetitions each; although the measurements were conducted during various phenological stages between April and September, no fixed areas were used, but the transect orientation, perpendicular on elevation contour lines, was kept.

The phytocoenological sampling was performed according to the Zürich-Montpellier School, on the same slope area, on 500 m^2 sample areas, in 10 repetitions. The tree biomass was computed as a function of their volume using dendrometric tables (Giurgiu et al. 1972) and the average density of the beech tree wood in that region (Paucă-Comănescu 1981). The biomass of the herbaceous layer was determined seasonally, cutting the above-ground part of all components (herbs, small plants, saplings, bryophytes) on 0.25 m^2 areas; the samples were sorted in the laboratory by species, dried in the stove at 85^{0}C and the smallest specimens were weighed with a precision of three decimals. The necromass was collected from the same areas. The plant diversity was evaluated with the Simpson-Pielou index of diversity.

$$D = 1 - \frac{\sum ni(ni-1)}{N(N-1)}$$

Table 1 Localization of the surveyed areas

Lunca Mare	Şotrile
Habitat R4111 South-Carpathian beech forests (*Fagus sylvatica*) and fir forests (*Abies alba*) with *Cephalanthera damasonium* ▪ Type of forest: 4213 Hill beech forest with superficial soils on limestone substratum ▪ Altitude: **490 m**, strongly irregular relief, in some areas the limestone rock reached soil surface. ▪ Exposition E. Inclination of about 25^0 ▪ Soil **humico-calcareous (rendzina with mull)** not uniform, mull humus, calcic, poorly skeletal, clay texture up to skeletal, sometimes the rock reaches the soil surface, properly aerated, properly drained; (pH 5.5-6.5) during the vegetation season. The soil reaches more heat because of the limestone substratum (calcite).	**Habitat R4106 South-Carpathian beech forests (*Fagus sylvatica*) and fir forests (*Abies alba*) with *Hieracium rotundatum* (syn. *Hieracium transsylvanicum*)** ▪ Type of forest: 4151 Mountain beech forest with *Luzula luzuloides* ▪ Altitude: **600 m** ▪ Exposition: N N E. Inclination 25^0 ▪ Soil **districambosol (brown acid)**, oligobasic, moderate and poorly humiferous, median – deep, clay-sandy texture, variable edaphic volume, small-median; (pH 4.0-5.5); low trophicity, little available water.

The soil acidity was determined from soil samples collected from the top 10 cm, stored in plastic bags and subsequently analysed in the laboratory using a "Consort C532" electronic pH meter.

Results and discussion

Biodiversity

The quantitative measurements of biodiversity at the tree layer level shows clear differences between the two beech forests (Table 2); at SO we can talk about the absolute dominance of *Fagus sylvatica*, while at LM other deciduous species, accounting for only about 10%, are found as well. Quantitatively, the most important of them are *Cerasus avium* and *Acer pseudoplatanus*; however, they all are in a subdominated or even dominated position.

The tree populations are, however, much more diverse (Table 2) even at SO, if we examine the biotic reserve (seedlings) existing in the herbaceous layer as small plants and saplings. All these species are found in the hill deciduous forests, forming a suite of accompanying species; thus, it is possible that, within a new structure, years later, they find a place in the tree layer. The species richness is more than double in the young stage compared to the composition of the tree layer, reaching nine species at LM and four at SO.

The herbaceous layer, in terms of numeric composition, is much wealthier than the tree layer; also the dynamics of these species is much more active, some of them disappearing earlier and other appearing later during the same growing season (Table 3).

We observed typical vernal species, with short life cycles, such as *Erytronium dens-canis* or *Gagea pratensis*, but also species which appear early in spring, bloom and multiply a lot in spring and stay throughout the vegetation period, such as *Lathyrus vernus*.

Among the estival species, next to the typical ones which appear in spring and grow and multiply intensely in summer, there are species such as the *Hedera helix* liana, which persist over winter, dominating even quantitatively the vernal season; other species expand only in late summer. If we take into consideration species whose numeric abundance accounts for more than one percent, at least at a certain moment in their annual development, we find that they are more numerous in the LM beech forest than in the SO beech forest (20 species versus 12). Their total number is also higher in LM beech forest, 100, compared to 78 in SO beech forest (Table 4a, b). A particular attention must be paid to the orchid species characteristic to the phytocoenoses and to the LM "habitat"; they appear late and in very low numbers, which makes them insignificant both in terms of numbers and as frequency. The frequency of these orchids' presence is superior in LM compared to SO, both as number of specimens and as number of species; this is an important fact given that they are relevant for the characterization of one of the habitat types.

Table 2 Tree composition in canopy and herb layer

Species	Tree relative numerical abundance %			
	Tree layer		Herb layer (natural regeneration)	
	Lunca Mare	Șotrile	Lunca Mare	Șotrile
Fagus sylvatica	91.5	100	50	75
Cerasus avium	4.5	0	1	0
Acer pseudoplatanus	2.0	0	2	0
Sorbus torminalis	2.0	0	3	0
Fraxinus excelsior	0	0	20	1
Acer platanoides	0	0	10	0
Acer campestre	0	0	8	0
Sorbus aucuparia	0	0	5	0
Carpinus betulus	0	0	1	20
Betula pendula	0	0	0	4

The species typical to the other type of habitat, *Hieracium transsylvanicum*, is much better represented numerically than most of the present species (Table 3), but less than the other acidophilous species (*Luzula luzuloides, Calamagrostis arundinacea*), which define the type of forest much more rigorously. No vernal species have been identified in this phytocoenosis.

Following the analysis of the phytocoenological surveys (Table 4 a, b), the two beech forests were included in different associations, namely *Epipactieto-Fagetum* (Resmeriţă, 1972) for LM and *Hieracio rotundati-Fagetum* (Vida 1983, Täuber 1987) for SO.

Table 3 Numerical abundance dynamics of plant populations from Lunca Mare and Şotrile

Lunca Mare			
SPECIES	Relative numerical abundance (%)		
	April	May	September
Spring			
Erythronium dens-canis	4.76	0	0
Gagea pratensis	1.86	0	0
Lathyrus vernus	1.99	3.71	0.91
Summer			
*Hedera helix**	42.20	17.66	11.84
Fagus sylvatica juvenils	7.12	15.73	8.64
Viola reichenbachiana	5.58	13.35	11.54
Acer platanoides juvenils	2.67	1.19	1.72
Campanula trachelium	2.49	5.34	0.61
Festuca drymeja			19.03
Fraxinus excelsior juvenils		5.64	7.79
Euphorbia amygdaloides	1.41	1.19	2.53
Sanicula europaea	1.99	3.71	3.34
Cerasus avium juvenils	1.13	1.59	1.72
Galium schultesii	2.40	4.15	3.44
Calamagrostis arundinacea	3.72		
Viola canina	1.72	0.15	2.63
Carex digitata	0.63	3.56	9.62
Sorbus aucuparia juvenils	1.22		
Acer pseudoplantanus juvenils		1.34	1.19
Aegopodium podagraria	4.44	4.15	0.40
Diagnostic species			
Epipactis helleborine			0.10
Cephalanthera damasonium		0.15	0.15
Platanthera bifolia		0.15	
Cephalanthera longifolia		0.20	

Other species present in samples: *Acer campestre* (seedlings), *Galium odoratum, Evonymus verrucosa* (seedlings), *Clematis vitalba, Lilium martagon, Hieracium rotundatum, Carex praecox, Luzula luzuloides, Carex sylvatica, Cerastium arvense, Evonymus europaeus* (seedlingspuieţi), *Crataegus monogyna* (seedlings), *Polygonatum multiflorum, Moehringia trinervia, Stachys sylvatica, Quercus petraea* (seedlings), *Geranium robertianum, Lathyrus pratensis , Veronica montana, Viburnum lantana (puieţi), Carex pilosa, Thalictrum aquilegiifolium, Luzula sylvatica, Fragaria vesca, Ligustrum vulgare, Tamus communis, Mycelis muralis, Cornus mas* (seedlings), *Geranium sanguineum, Carpinus betulus* (seedlings), *Epilobium angustifolium, Galium pedemontanum, Cirsium oleraceum, Rumex crispus, Scrophularia nodosa, Salvia glutinosa, Cornus sanguinea* (seedlings), *Campanula rapunculoides, Senecio fuchsii, Alliaria petiolata, Sorbus torminalis* (seedlings), *Melittis melissophyllum, Pulmonaria officinalis, Lathyrus tuberosus, Actaea spicata, Poa nemoralis, Rosa canina* (seedlings)

Şotrile			
SPECIES	Relative numerical abundance (%)		
	April	May	September
Summer			
Luzula luzuloides	48.88	27.92	38.95
Poa nemoralis	20.51	8.56	8.92
Hieracium transsylvanicum	8.59	15.08	8.19
Carex digitata	5.00	13.71	13.38
Viola reichenbachiana	3.96	1.36	
Campanula trachelium	3.12	3.23	
Dentaria bulbifera	2.81		
Mycelis muralis	1.67	3.23	0.67
Fagus sylvatica juvenils	1.61	2.73	3.86
Calamagrostis arundinacea		10.04	22.57
Oxalis acetosella		3.41	
Fragaria vesca		3.23	0.07
Carpinus betulus juvenils		1.55	0.27
Diagnostic species			
Hieracium transsylvanicum	8.59	15.08	8.19

Other species present in the samples: *Moehringia trinervia, Veronica chamaedrys, Pyrola media, Hedera helix, Taraxacum officinale, Luzula sylvatica, Galium schultesii, Lathyrus pratensis, Veronica montana, Veronica urticifolia, Tussilago farfara, Poa nemoralis, Cerastium glomeratum, Campanula abietina, Crataegus monogyna* (seedlings), *Prunella vulgaris, Epilobium angustifolium, Epilobium montanum, Stachys sylvatica, Trifolium repens, Betula pendula* (seedlings), *Plantago media, Cephalanthera damasonium, Rosa canina* (seedlings), *Chrysanthemum leucanthemum, Campanula abietina, Clematis vitalba, Salvia glutinosa, Neottia nidus-avis, Plathanthera bifolia, Geranium robertianum, Alliaria petiolata, Carex sylvatica*

Table 4a *Epipactieto-Fagetum* Resmeriță 1972 association at Lunca Mare

***Epipacteto-Fagetum* Resmeriță 1972**											
Releve number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**K**
Area (square meter)	500	500	500	500	500	500	500	500	500	500	
Vegetation height - trees (m)	35	30	32	35	35	30	32	30	35	35	
- shrubs (m)	3	3	2,5	4	3	3	3	4	3	3	
- herbs (cm)	25	30	50	30	30	35	40	50	50	40	
Covering (%) - trees	75	70	65	80	70	75	80	70	65	85	
- shrubs	1	1	2	1	1	2	3	5	1	1	
- herbs	40	40	20	25	40	30	30	40	25	40	
Exposition	E	SE	E	E	SE	E	E	E	E	E	
Slope (degrees)	25^{0}	15^{0}	30^{0}	25^{0}	10^{0}	15^{0}	20^{0}	25^{0}	10^{0}	15^{0}	
Diagnostic species [											
Fagus sylvatica	3- 4	4	4	4	4 - 5	4	3	4	4	4	V
Epipactis helleborine	+		+1		+			+		+1	III
Cephalanthera longifolia	+			+			+		+	+	III
Epipactido-Fagenion											
Neottia nidus-avis	+		+						+		II
Actaea spicata	+		+				+			+	II
Symphyto-Fagion											
Galium odoratum	+1			+	+		+		+		III
Melica uniflora		+	+		+				+	+	III
Dentaria bulbifera	+		+		+			+			II
Epilobium montanum	+		+		+		+		+	+	III
Fagetalia											
Carex sylvatica	+1				+		+1		+	+	III
Circaea lutetiana			+1					+		+	II
Asarum europaeum		+			+		+		+		II
Euphorbia amygdaloides	+		+		+			+		+	III
Geranium robertianum		+		+				+			II
Lathyrus vernus		+	+1		+				+	+	III
Lamium galeobdolon		+1			+				+	+	II
Mycelis muralis		+	+		+		+	+			III
Pulmonaria officinalis		+	+		+						II
Rubus hirtus	+			+			+			+	II
Calamagrostis arundinacea	+1	+1	1	2			+	+1	1	2	IV
Hieracium transsylvanicum			+	+					+	+	II
Epilobium montanum	+			+				+		+	II
Carex digitata	+		+	+	+		+		+	+	IV
Luzula luzuloides	+		+		+			+		+	III
Viola reichenbachiana		+		+				+		+	II
Querco-Fagetea											
Brachypodium sylvaticum	+	+		+1			+	+	+	+	IV
Crataegus monogyna [	+		+		+		+			+	III
Viburnum lantana		+	+				+	+			II
Ligustrum vulgare		+		+	+		+	+		+	III
Lathyrus niger		+	+					+	+		II
Hedera helix		+		+				+		+	II
Campanula trachelium	+		+		+		+		+		II
Variae Syntaxa											
Equisetum sylvaticum	+	+		+			+		+	+	III
Alliaria petiolata		+	+		+		+	+			III
Aegopodium podagraria	+		+	+	+		+		+	+	IV
Species in a single releve*:* *Astragalus glycyphyllo* (8), *Prunella vulgaris* (10), *Galium schultesii* (3), *Dryopteris filix-mas* (7), *Clematis vitalba* (4), *Rubus caesius* (7), *Geranium robertianum* (2).											

Table 4a (fellow-up)

Other species inventoried within the research site: *Acer campestre, Acer platanoides, Acer pseudoplatanus, Campanula rapunculoides, Carpinus betulus, Carex pilosa, Carex praecox, Chamaecytisus hirsutus, Cephalanthera damasonium, Cerasus avium (Prunus avium), Chamaenerion angustifolium* (*Epilobium angustifolium*), *Cirsium oleraceum, Cornus mas, Cornus sanguinea, Cruciata pedemontana* (*Galium pedemontanum), Cruciata glabra*(*Galium vernum)*, *Cynodon dactylon, Daphne mezereum, Dactylis glomerata, Erythronium dens-canis*, *Equisetum telmateia, Euphorbia epithymoides* (*E. polychroma*), *Evonymus europaeus, Evonymus verrucosus, Festuca drymeja, Festuca gigantea, Fragaria vesca, Fraxinus excelsior, Gagea pratensis, Lathyrus hallersteinii, Lathyrus pratensis, Lathyrus tuberosus, Lathyrus venetus*, *Lilium martagon, Luzula sylvatica, Melittis melissophyllum, Moehringia trinervia, Quercus petraea, Platanthera bifolia, Poa nemoralis, Polygonatum multiflorum, Populus alba, Rhinanthus minor, Rumex crispus, Rosa canina, Salvia glutinosa, Sanicula europaea, Senecio ovatus* (*S. fuchsii*), *Sorbus aucuparia, Sorbus torminalis, Stachys sylvatica, Stellaria media, Thalictrum aquilegiifolium, Tamus communis, Viola canina, Veronica montana, Taraxacum officinale.*

Table 4b *Hieracio rotundati-Fagetum* (Vida 1983) Täuber 1987 association at Şotrile

***Hieracio rotundati-Fagetum* (Vida 1983)Täuber 1987**												
Releve number		1	2	3	4	5	6	7	8	9	10	K
Area (square meter)		500	500	500	500	500	500	500	500	500	500	
Vegetation height	- trees (m)	35	32	35	30	35	32	35	30	35	35	
	- shrubs (m)	3	3	2,5	3	4	3	4	4	3	3	
	- herbs (cm)	50	60	50	55	45	40	55	50	40	40	
Covering (%)	- trees	70	75	70	75	65	80	70	75	80	80	
	- shrubs	1	5	2	5	2	3	5	4	5	5	
	- herbs	40	35	40	40	40	35	25	20	15	25	
Exposition		N	N	N	N	N	N	N	NV	N	N	
Slope (degrees)		15^0	15^0	15^0	15^0	10^0	15^0	20^0	15^0	20^0	15^0	
Diagnostic species												
Fagus sylvatica		4	4	4	4-5	4	4	4-5	4	4	4	V
Hieracium transsylvanicum		+	+		+	+1	+	+		+	+1	IV
Calamagrostio-Fagenion												
Calamagrostis arundinacea		2	+1	1		1-2	2		1	2	+1	IV
Luzula luzuloides		1	+	+1	+		+1	1		+	+1	IV
Veronica officinalis			+	+		+	+		+			III
Lathyro hallersteinii-Carpinenion												
Galium schultesii		+		+1		+	+			+1		III
Dentaria glandulosa		+	+		+		+	+				III
Lathyrus vernus		+	+	+1		+		+		+	+	IV
Festuca drymeja				+	+1	1		1			+	III
Cerasus avium		+1			+		+				+	II
Fagetalia												
Fragaria vesca		+		+	+			+	+	+		III
Viola reichenbachiana			+	+		+	+	+1			+	III
Veronica chamaedrys		+			+	+			+	+		III
Epilobium montanum		+		+		+	+			+	+	III
Carex digitata		+		+	+	+		+	+		+	IV
Dentaria bulbifera			+		+		+		+			II
Cephalanthera damasonium		+		+		+		+			+	III
Galium odoratum			+		+		+		+			II
Stachys sylvatica				+		+	+		+		+	III
Dryopteris filix-mas		+			+	+		+				II
Cornus sanguinea			+	+		+	+		+		+	III
Carex sylvatica				+	+			+			+	II
Geranium robertianum [			+	+		+		+			+	III
Euphorbia amygdaloides		+			+	+	+		+	+		III

Table 4b (fellow-up)

Lamium galeobdolon	+		+	+			+		+		III
Mercurialis perennis		+	+		+			+		+	III
Sanicula europaea	+		+	+	+		+		+	+	IV
Anemone ranunculoides	+		+		+		+		+		III
Querco-Fagetea											
Campanula trachelium	+		+		+	+	+	+		+	IV
Poa nemoralis		+		+		+			+		II
Mycelis muralis		+	+		+		+			+	III
Hedera helix	+		+	+		+		+	+		III
Brachypodium sylvaticum	+		+		+1			+	+1		III
Acer platanoides	+		+	+		+		+			III
Rosa canina	+			+	+		+		+	+	III
Fraxinus excelsior	+	+		+		+		+		+	III
Corylus avellana		+	+		+	+		+		+	III
Anemone nemorosa	+	+		+	+		+	+		+	IV
Variae Syntaxa											
Hieracium pilosella	+		+	+			+			+	III
Cruciata pedemontana		+		+	+		+	+			III
Campanula bononiensis		+	+			+				+	II
Prunella vulgaris		+	+		+		+		+		III
Astragalus glycyphyllos	+		+		+	+				+	III
Luzula sylvatica			+		+		+		+		II
Clematis vitalba	+		+		+	+		+			III
Rubus caesius	+		+		+		+		+		III
Species in a single releve : *Corallorrhiza trifida* (5), *Digitalis grandiflora* (8), *Viola canina* (3), *Melittis melissophyllum* (6), *Sambucus nigra* (2), *Aegopodium podagraria* (7), *Polygonatum odoratum* (10), *Hypericum maculatum* (9)											
Other species inventoried within the research site: *Arrhenatherum elatius*, *Alliaria petiolata* (*A. officinalis*), *Agrostis stolonifera, Betula pendula* (*B. verrucosa*), *Campanula abietina, Campanula persicifolia, Campanula rapunculoides, Carpinus betulus, Cerastium arvense, Crataegus monogyna, Cornus mas, Chrysanthemum leucanthemum* (*Leucanthemum vulgare*), *Lathyrus pratensis, Lotus corniculatus, Moehringia trinervia, Plantago lanceolata, Pyrola media, Taraxacum officinale, Trifolium repens, Tussilago farfara, Thymus pannonicus* (*T. marschallianus*), *Thymus pulegioides, Veronica montana, Veronica urticifolia.*											

The characteristic elements of the LM association are *Epipactis helleborine* and *Cephalanthera longifolia* from the herbaceous layer, next to the clear dominance of *Fagus sylvatica*. They have a high frequency of occurrence (classes III-V) and indicate the presence of limestone substrates, with a higher thermophilous character and with a meso-eutrophic soil (high level of base saturation). The common accompanying species are mull-humus lovers *(Lathyrus vernus, Sanicula europaea, Lamium galeobdolon, Euphorbia amygdaloides*), numerically well represented in the quantitative surveys (Table 4). This forest association is better known in western Romania, in the Apuseni Mountains and along the Danube Gorges, but even there it has lower coenotic cohesion and expressivity than the central-European vicariant (*Cephalanthero-Fagion* Tx, 1955). Compared to the similar phytocoenoses in western Romania and central Europe, they lack *Fraxinus ornus*, probably because of the slightly colder weather; the replacement species in eastern Romania is, probably, *Fraxinus excelsior*.

The characteristic herbaceous species of the *Hieracio rotundati-Fagetum* association from SO is *Hieracium transsylvanicum* (syn. *Hieracium rotundatum*), known for its acidophilic character, next to *Luzula luzuloides* or *Calamagrostis arundinacea*. The species has a high frequency of occurrence (class IV) in the Doftana Valley phytocoenoses and the forest association is frequent in the area, being typical for the Carpathians.

The richness of both herbaceous and woody species is relatively large in both beech forests studied; however, the estimated values show a higher species richness in the LM beech forest compared to SO beech forest regardless of botanical method applied. The species with higher ecological significance (represented by populations with high numeric abundance or with high amounts of biomass) are more numerous in the LM beech forest than in the SO beech forest (Table 5).

The Simpson-Pielou diversity index shows higher values in the herbaceous layer, 0.841-0.9222 in LM and 0.7501-0.9223 in SO. Overall, these values which vary seasonally, indicate a high diversity peak during summer and may characterize the entire phytocoenosis. However, the tree layer, considered independently, has a very low diversity, just 0.2006 in LM and zero in SO.

If most of the times a large diversity of species has no positive influence on the ecosystemic functions (Mokany et al. 2008), in the case of the two beech forests studied, the species richness is larger in the most productive beech forest, both in the tree layer and in the herbaceous layer, indicating, thus, a positive correlation between diversity and productivity.

The mosses (Bryophyta), next to the vascular plants, complement the biodiversity of the primary producers. In the two beech forests from the Doftana Valley 14 different species have been identified. On the tree trunks, the species are common to both sites (Table 6a). At soil surface, the moss species are completely different between the two phytocoenoses, probably because of the difference in soil acidity (Table 6b). Although it was not possible to represent quantitatively the participation of each species, we observe that in the SO beech forest, on more acidic soil, a larger mass of mosses have growth, particularly in spring and in early summer (Table 10).

The macromycetes identified in the Doftana Valley beech forests were not numerous during the study period, probably because of the very dry soil, the fructifying bodies appearing less frequently. In the LM beech forest the following species were collected: *Pleurotus pulmonarius* (Fr.) Quél., *Polyporus varius* (Pers.) Fr., *Trametes versicolor* (L.) Lloyd, *Stereum hirsutum* (Willd) Pers. and genera *Coprinus* (sp.); in the SO beech forest were collected *Russula virescens* (Schaeff.) Fr., *Xylaria polymorpha* (Pers.) Grev., *Stereum hirsutum* (Wild) pers. and a species of *Boletus*.

Table 5 Number of herbaceous species inventoried

Sites	Total inventoried species	Inventoried in phytosociological relevees	Inventoried in samples	
			density	biomass
Lunca Mare	100	42	71 (20)	44 (14)
Şotrile	78	54	47 (14)	33 (9)

( ) -quantitative relevant species as ecological indices

Table 6a Tree trunk bryophytes from Doftana Valley

Lunca Mare	Şotrile
Frullania dilatata (L.) Dumort.	*Frullania dilatata* (L.) Dumort.
Radula complanata (L.) Dumort	*Radula complanata* (L.) Dumort
Leskea nervosa (Brid.) Myrin	*Leskea nervosa* (Brid.) Myrin

Table 6b Soil bryophytes from Doftana Valley

Lunca Mare	Şotrile
Metzgeria furcata (L.) Corda var. *ulvula* Nees	*Polytrichum formosum* Hedw.
Leskea nervosa (Brid.) Myrin	*Pogonatum nanum* (Schreb. ex Hedw.) P. Beauv.
Ctenidium molluscum (Hedw.) Mitt	*Hypnum cupressiforme* Hedw.
Atrichum undulatum (Hedw.) P. Beauv.	*Tortella tortuosa* (Hedw.) Limpr.
Orthodicranum montanum (Hedw.) Loeske	*Schistidium apocarpum* (Hedw.) Bruch & Schim
Mnium spinulosum Bruch & Schimp.	*Seligeria pusilla* (Hedw.) Bruch & Schimp.

Table 7 Biometric indices of beech trees within the forest canopy

Site	Height (m)			Diameter (cm)			Volume (mc)		
	mean ± average error (Sx)	Variation limits	Variation coefficient (S%)	mean ± average error (Sx)	Variation limits	Variation coefficient (S%)	mean ± average error (Sx)	Variation limits	Variation coefficient (S%)
Lunca Mare	28.7 ± 2.49	23.0 - 33.5	16.61	33.33 ± 7.9	20.06-56.69	30.8	1.420 ± 0.78	0.40-4.20	69.26
Şotrile	23.76 ± 1.12	20.00-26.5	6.252	31.57 ± 6.28	18.47-59.87	26.51	1.023 ± 0.45	0.20-3.87	62.89

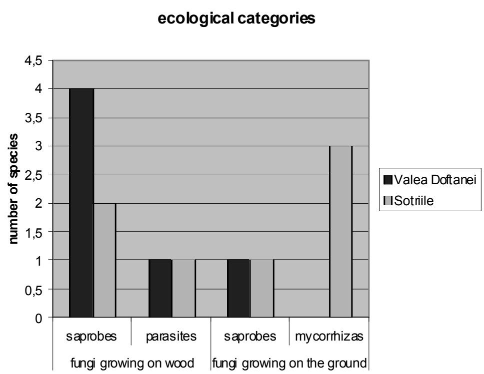

Figure 1 Macromycete species occurrence in the two beech forests analyzed

The corticolous species were the most numerous at LM, and the mycorrhizal ones were found only at SO (Fig. 1). The parasitic species, as well as the saprophytic species, were less present, but they appeared in a similar manner on tree trunks and on soil on both study sites.

Elements of structure and productivity

The most numerous beech trees in the LM site displayed average to high biometric characteristics for the beech forests in Romania (Table 7). The variability in size (height and diameter) is caused not only by different ages, but also by a larger extent of the individual position within the phytocoenosis, because the very diverse microrelief provides different conditions of support for the trees at the foot of the slope, on the steep slope or on the ridge of the hill. In addition to this is the position within the canopy and the changes in light following selective cuts of older trees, in both forests, but particularly in LM (up to 10% decrease in number).

The canopy cover is quite high (90%), not just because of the mature trees, but also because of the seedlings, thin and tall (10-12 m), and of the shrubs competing for light; the mature shrubs are almost, as high and little branched, atypical for *Crataegus monogyna* and *Cornus mas*, species accounting for the numeric majority in the phytocoenoses studied. The seedlings reaching to the lower layer belong exclusively to the dominant species in SO, while at LM *Fraxinus excelsior*, *Acer platanoides* and *Cerasus avium* are also found.

Overall, beech populations are five meters taller in average at LM than at SO, but two centimeters thinner (Table 7); the average volume is almost 1/3 larger at LM than at SO. While height variability among the population is higher at LM than at SO, trunk diameter's variability among the population is lower at LM than at SO, where the thinner and the thicker (60 cm) trees were found.

Compared to other beech trees in Romania, the beech forest with acidophilous flora (SO) respects the limits of variation known for this type of phytocoenosis, while the orchid beech forest has biometric characteristics closer to those of the beech tree from highly productive beech forests, with mull flora (Paucă-Comănescu et al. 1989).

The tree density in these two phytocoenoses is quite low (Table 8), but the lowest is in the LM`s beech forest. The variability of the local distribution of specimens is very high and it is attributed to the very diverse microrelief with extremely unequal conditions in both sites. Both values were influenced by cuttings, but nonetheless they are below the values for productive forests, as compared to the data from the dendrometric tables and knowing that only the poorly productive forests have high tree density.

The volume and the biomass accumulated in the tree layer (Table 10) place these phytocoenoses at the lowest limit of the highest productive forests, as defined by the dendrometric reference data for the corresponding age of beech forests (Giurgiu et al. 1972). However, the difference between the capacity of wood accumulation and, therefore, production, is clearly higher in the LM beech forest than in the SO beech forest, which proves that the soil fertility level in the limestone substrate site is much higher, even not uniform (the site includes sometimes areas with steep slopes, deep ravines, which favor strong shadowing of trees). In these conditions, the wood biomass in the acidophilous beech forest from SO, measured at the level of trunks, accounts just over 70% of the biomass accumulated in LM during the same period.

The contribution of the tree layer is essential in each forest phytocoenosis. The numeric structure and the productive capacity of the herbaceous layer can also be measured, but they have different relevance. The overall numeric density of the herbaceous layer is very high (Table 9), being about 200-300 times higher than that of the tree layer. The herbaceous density may vary extensively during the period of vegetation, almost twice, but it was consistently higher in the SO beech forest than in the LM beech forest. This is one of the least stable structural elements (very high coefficient of variation), considerably influenced by the species entering in this layer.

The accumulation of phytomass in the herbaceous layer, which includes, also the wood species saplings, is very different between both beech forests (Table 10). Although both phytocoenoses have a discontinuous herbaceous layer, poorly developed, with species having a narrow habitus and low individual biomass production, the amount of biomass accumulated during the period of maximal growth (May) reaches 32 g DM/m^2 at LM and 24 g DM/m^2 at SO (DM= dry matter). The biomass accumulated in the herbaceous layer reaches average to high values within the variation known for the phytocoenoses edified by beech trees. It is met in both high and poor

Table 8 Production capacity indices for the trees layer

Site	Trees' density (individual/ha)		Volume (mc/ha)		Herbaceous biomass (t/ha dry matter)	
	media ± average error (S**x**)	Variation coefficient (S%)	media ± average error (S**x**)	Variation coefficient (S%)	media ± average error (S**x**)	Variation coefficient (S%)
Lunca Mare	340 ± 163	48	444.2 ± 51.07	16.344	222.08 ± 25.56	16.35
Şotrile	390 ± 128	36	327.27 ± 11.42	5.19	163.66 ± 5.73	5.21

Table 9 Density dynamics of the herbaceous layer

Site	Density of herbaceous layer (ind/m^2)				Coefficient of variation (%)
	April	Mai	September	Average	
Lunca Mare	**88.24** ± 56.79	**53.12** ± 26.92	**79.34** ± 38.40	73.5	87-62
Şotrile	**123.94** ± 86.0	**136.80** ± 74.95	**200.27** ± 71.34	153.3	82-68

Table 10 Contribution of different phytomass components of the herbaceous layer (maximal period, May)

Phytomass categories		Biomass of herbaceous layer (g dry matter/m^2) Lunca Mare	Şotrile
Vascular plants	Herbaceous plants	22.48	16.04
	Different offspring	0.10	0.02
	Seedling plants	8.95	2.39
	Total	31.53	18.45
Bryophytes		0.18	5.06
Total living phytomass		**31.71**	**23.51**
Necromass		**390.50**	**367.17**
Total phytomass		422.21	390.68

productive beech forests and mirrors much more closely to the local substratum conditions (Paucă-Comănescu et al. 1989). Farley and Fitter (1999) identified a fast response of plant growth only in nitrogen-rich soil areas, which would account also for the high variability identified by us as an herbaceous mosaic. Although this variation is observed in soil up to two meters below the surface, the variation is 2-5 times higher in the first 20 cm, the grasses having an equal benefit with the trees at this depth. The same authors pointed out an increased amount of nutrients in spring and early summer, precisely when the herbs grow with maximum speed, followed by a contraction and a restoration of the amount of nutrients in autumn, when the grasses shoots abound. The seasonal dynamics of the nutrients has also been confirmed by other authors, both in the forest and pasture phytocoenosis. We can, thus, consider that the production of the herbaceous species correlates directly with the very active dynamics of the soil surface nutrients resulting from the gradual decay of the phytomass. Verheyen et al. (2004) suggested a model of the forest metapopulations (herbaceous) dynamics, differentiated by the capacity of colonizing new territories, and recommended its utilization at the landscape scale in nature conservation and ecological restoration.

Two thirds of the biomass of the herbaceous layer are produced by herbs and lianas, completed by up to eight percent by the constant and sustainable contribution of seedlings and shrubs (Table 10). The difference in the amount of phytomass in the lower layer of the two phytocoenoses is caused by the accumulation of the herbaceous biomass (22.48 g versus 16 g/m^2) and not by the other biotic components. In certain sites, such as the acidophilous beech forest from SO, the bryophytes can also have a significant contribution, but single sided, while the phytomass contributed by the growth of the tree juveniles keeps its proportion in relation to the total accumulation, although their production in the two phytocoenoses studied is not equal.

The resulting necromass is high, at least 100 times higher than the biomass of the herbaceous layer; it originates mainly from the fallen leaves from trees during the previous years (Table 10). The value of the accumulation depends on the annual tree foliar mass, on the speed of decay and on the stability of the deposit area (on steeper slopes denuded of vegetation, they move to other areas or even to other ecosystems).

The ratio of living phytomass to necromass is significantly influenced by the foliar production of the trees, but the maximal herbaceous biomass does not entirely reflect the necromass of the herbaceous layer because, as observed (Table 12), many herbaceous populations have a shorter life cycle, and their mass turns into necromass over a shorter period; this phytomass can enlarge that produced by other species which appear and disappear later.

The importance of the herbaceous species as biomass producers is very different, and many times it has no connection to the characteristic herbaceous species. Anyhow, in the LM beech forest, the herbaceous layer is dominated and supported by *Hedera helix*, sempervirent species with peak production in May; next to it are *Lathyrus vernus* and *Carex sylvatica, Calamagrostis arundinacea* and *Carex digitata*. As shown before, the characteristic orchid species are qualitatively numerous compared with other types of beech forests, but they are neither among the productive species of the herbaceous layer, nor among the highly dense species of the phytocoenosis. The question is, thus, whether there are other species that reflect the same site and coenotic conditions, but with a more significant production.

In the SO beech forest, the herbaceous species dominating the layer are moderate or high acidophilous (*Carex digitata, Luzula luzuloides*), but the species characteristic to the association, *Hieracium transsylvanicum*, also shows up, although in lower numbers.

We observed for both phytocoenoses that *Fagus sylvatica* juveniles have an important contribution to the layer biomass, ranking 3rd and 2nd as producers of the herbaceous layer. Similarly, *Hedera helix* and the acidophilous species are important producers within the herbaceous layer of both phytocoenoses, and particularly so in LM.

The importance of herbaceous versus woody biomass, as different layers of the same phytocoenosis is reduced to 0.15% in the phytocoenoses studied, as shown in Table 12. The accumulation of total phytomass including the necromass is higher, representing about two percent of the tree biomass. The differences between phytocoenoses are not relevant in these disproportionate accumulations between the main components of the primary producers. We must not forget, however, that the annual production of beech forests has other values than the overall accumulation, over a period of 100 years.

If in the pasture ecosystems the dimensions of the component bioforms are quite similar, in the forest ecosystems it is difficult to interpret the Grime's (1988) functional value of "dominant-subdominant and accidental" species involved in the relation plant diversity - ecosystem functions, production being one of them. At the subsystem level - herbaceous layer - where the ratio production to species richness could be analyzed, particularly for the subdominant and accidental species given their comparable dimensions, it seems possible to determine these categories of species. The concept is demonstrable by the fact that the LM beech forest has more species and also a higher herbaceous biomass, while in SO there are

Table 11 Seasonal dynamics of the biomass of herbaceous layer populations (2007)

Lunca Mare					Şotrile				
Species	Populations green biomass (g/m^2)				Species	Populations green biomass (g/m^2)			
	April	May	July	September		April	May	July	September
Spring					**Summer**				
Erythronium dens-canis	2.41	0	0		*Carex digitata*	6.06	9.46	2.18	2.56
Gagea pratensis	0.25	0	0		*Fagus sylvatica**	5.06	3.49	0.07	4.40
Lathyrus vernus	1.11	12.36	2.18		*Luzula luzuloides*	5.01	9.97	8.00	0.55
Summer					*Poa nemoralis*	1.86	0.66	0.13	1.74
Hedera helix	13.07	31.93	7.28	3.01	*Hieracium transsylvanicum*	1.80	7.94	0.86	0.26
Carex sylvatica	8.62	9.22	8.78	1.57	*Campanula trachelium*	0.17	3.60	0.13	0.13
*Fagus sylvatica**	7.49	9.50	9.10	11.20	*Mycelis muralis*	0.03	2.47	0.39	0.07
Calamagrostis arundinacea	5.38	6.78	6.90	3.78	*Viola reichenbachiana*	0.78			
Carex digitata	4.70	2.65	0.23	1.39	*Hedera helix*	0.62		1.98	1.54
Aegopodium podagraria	3.59	4.81							
Stachys sylvatica	1.73	2.56							
Acer platanoides *	1.54	0.62	0.27	0.42					
Lilium martagon	1.34	2.92							
Sanicula europaea	1.00	9.84	5.21	6.27					
Viola reichenbachiana	0.95	1.89	1.07	0.79					
Other species present in samples: *Carex praecox Galium schultesii, Cerasus avium*, Melittis melissophyllum, Melica uniflora, Viola canina, Crataegus monogyna*, Cynodon dactylon, Galium odoratum, Luzula luzuloides, Poa nemoralis, Stellaria media, Viburnum lantana*, Acer pseudoplatanus*, Acer campestre*, Cornus mas*, Campanula trachelium, Fraxinus excelsior*, Hieracium transsylvanicum, Dactylis glomerata, Taraxacum officinale, Euphorbia epithymoides, Festuca drymeja, Festuca gigantea, Lathyrus pratensis, Rubus hirtus, Alliaria petiolata, Cephalanthera longifolia, Euphorbia amygdaloides, Cornus sanguinea**					**Other species present in samples**: *Crataegus monogyna*, Rosa canina*, Stachys sylvatica, Veronica montana, Taraxacum officinale, Epilobium montanum, Campanula rapunculoides, Calamagrostis arundinacea, Carex sylvatica, Hieracium pilosella, Agrostis stolonifera, Plantago lanceolata, Carpinus betulus*, Campanula abietina, Viola canina, Fragaria vesca, Cornus mas, Betula pendula, Veronica urticifolia, Campanula persicifolia, Chrysanthemum leucanthemum, Galium schultesii, Brachypodium sylvaticum, Fraxinus excelsior*				

* woody species represented through seedlings and offsprings

Table 12 Organic matter and living phytomass accumulated (t/ha dry matter) in the surveyed beech forests at the same time

Total biomass of herbaceous layer	Lunca Mare	0.317
	Şotrile	0.235
Maximum total phytomass (herbaceous and tree leaves) per hectare	Lunca Mare	4.2
	Şotrile	3.9
Tree layer woody biomass	Lunca Mare	222.08
	Şotrile	163.66

fewer species and a lower amount of herbaceous biomass. The issue is whence and when are the dominant species in the forest herbaceous layer, given that they change monthly.

The Doftana Valley beech forests analyzed the range within the current limits of diversity and productivity for the beech forests in Romania. The orchid (*Cephalanthera* and *Epipactis*) beech forest is a type with intermediate productivity, between the high and average productivity, at both tree and herbaceous layer, and, as far as we know, it is studied for the first time in the Romanian SE Carpathians in terms of biodiversity, phytocoenological composition, and, particularly, biological productivity.

Conclusions

The tree layer in the beech forests surveyed in Doftana Valley is monodominant or almost monodominant (*Fagus sylvatica* at least 94%) being an exception in the case of the hill beech forests from South Subcarpathians where a high diversity is known. However, the richness of woody species in the lower layer of the two phytocoenoses shows a higher competitiveness of *Fagus sylvatica* compared with the other species. The herbaceous layer displays a high diversity (Simpson / Pielou index is > 0.9222).

Although selective cuts have been performed in both forests, more intens in E*pipactieto Fagetum* (LM) than in *Hieracio rotundati - Fagetum* (SO) the aboveground woody mass as well as the biometric indices (height and diameter) are higher in LM. The current biometric and productive characteristics place the forests at the level of average to higher biological productivity among the beech forests from Romania and the best capacity was observed at the beech forest with orchids (222 compared to 163t/ha woody mass and 317 respectively 235 kg/ha herb mass).

Methodologically, the study of forest biodiversity in the herbaceous layer is better grasped through detailed inventories on small plots (0.25 m^2), in a large number of repetitions (more than 100), than through phytosociological surveys.

The old beech forests with a fundamental natural structure and regeneration, which we surveyed in Doftana Valley, should be selected as protected areas at the national level, because both of them are protected habitats within the European network NATURA 2000 (**9150** *Medio-European limestone beech forests of Cephalanthero-Fagion* and **9110** *Luzulo-Fagetum beech forests*).

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