Biomass in the herbaceous layer of spruce (*Pinaceae*) forest stands in Bulgaria*

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Abstract. Herbaceous layer in forest ecosystems is an important but not sufficiently investigated part of these communities. The above-ground biomass of the herbaceous layer in spruce forest stands in Bulgaria is investigated in the present study. The sample plots method was used. The average phytomass was estimated at 53 g.m^{-2}. The mixtoherbosa group was presented in all sample plots. Its highest store varied between 63 % and 95 %. The store of gramineous groups was around 4 % and young tree saplings came next in frequency. The groups of leguminous grasses (0.4 %), cyperaceous grasses (4 %) and ferns (18 %) can be found only in some sample plots.

Key words: above-ground phytomass, herbaceous layer, spruce forests

Introduction

The Norway Spruce [*Picea abies* (L.) H. Karst.] forests dominate in the coniferous belt in Bulgarian mountains. They participate with 4.6 % in the total forest area of the country, or represent 15 % of the area under coniferous species (Executive Forestry Agency 2010). Because of the importance of these forests for Bulgaria, they have been chosen as object of investigation in the project "Influence of the atmospheric depositions over the spruce stands bioproductivity". The present investigation is part of this multidisciplinary project.

In investigations of the functioning of vegetation communities, one of the main indexes is phytomass storage and bioproductivity. According to their changes, we can judge the state and processes in these communities.

Literature showed that so far the studies into forest communities were focused predominately on the biomass and the net primary production of main tree species. Only few investigations reported data on the herbaceous layer in the forest ecosystems, which represented less than 1 % of the total forest biomass. However, it could account for up to 90 % of the species composition and provide around 20 % of the overall litterfall with high nutrient content. Development of the forest after different biotic and abiotic disturbances to the canopy depends on the composition of the ground floor herb layer, as a place of intensive species and resource competition relationships (Gilliam 2007). Furthermore, information on ground flora carbon and nutrient storage and cycling is a vital input to forest growth, carbon and nutrient balance and dynamic models. Therefore, a more extensive research is necessary on this part of the forest ecosystems.

At national level, the studies of Kochev & al. (1978), Bondev & al. (1994), Lyubenova & al. (1998), and Dimitrova & al. (2011, 2014) are of special interest for the herbaceous layer primary production of forest ecosystems.

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At international level, the spruce stands are also object of investigation of their structure, composition and bioproductivity. Pristova (2011) has established stores of 3.9 t·ha^{-1} for the herbaceous layer during investigations of the spruce forests in Northeast Russia in the taiga zone. Cuttings and natural deforestation have influenced significantly the biodiversity, structure and biomass of the herbaceous layer. Alaback (1984) investigated the reaction of herbaceous vegetation and the change of the biomass amount in the herbaceous layers after logging at different stand age of *Picea sitchensis* (Bong.) Carrière and *Tsuga heterophylla* (Raf.) Sarg. Mack & al. (2008) studied the succession processes after fire in *Picea mariana* (Mill.) Britton communities and restoration of the biomass after a four-year period. Russell & al. (2014) have studied understory vegetation in the US Lake States in relation to the forest carbon stocks.

The aim of the present study is to measure and evaluate the above-ground biomass in the herbaceous layer of Norway Spruce stands.

Material and methods

The biomass of the ground flora was investigated in spruce stands of *P. abies*. The six stands have been studied in five sampling plots within each stand. Sample stands were determined in the spruce stands on the territory of the Petrohan Experimental and Educational Forestry Enterprise (EEFE Petrohan), Barzia village, which is situated on the northeastern slopes of the Western Balkan Range (Berkovitsa Divide). The territory belongs to the temperate-continental area, with average annual temperature of 10.4 °C and with average annual precipitation of 500–750 mm. The soils are *Humic Cambisols* (FAO). Natural vegetation on the northern slope of the Western Balkan Range is referred to the Illyric Phytogeographical Province (Kapralev 2002; Table 1, Fig. 1).

Table 1. Characteristics of the sample plots in the investigated stands.

Sample plot	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6
Compartment	182 b	155 p	69 m	69 к	82 z	120 b
Altitude, m	600	780	825	830	854	1428
Age, years	80	90	37	70	50	70
Exposure	N	SW	E	E	NE	W
Slope, degrees	13	8	8	5	13	3
Stand origin	artificial	artificial	artificial	artificial	artificial	artificial
Soil, FAO code	*Humic cambisols*	*Humic cambisols*	*Humic cambisols*	*Humic cambisols*	*Humic cambisols*	*Humic cambisols*

The above-ground phytomass of the herb layer was investigated by the sample-plots method (Rodin & al. 1968; Lyubenova 2009). Five experimental plots of 1 m^2 were randomly chosen in each sample stand in order to include all variations in microtopography, and the grass coverage. The above-ground herbaceous mass was collected from each plot in May, when most grass species are in maximum growth. The biological groups (leguminous, gramineous, cyperaceous grasses, mixtoherbosa, ferns, and young tree and bush saplings) were distinguished. The species determination has followed Jordanov (1973) and Delipavlov & al. (2003). The above-ground samples were dried at 85 °C for 48 hours to constant weight and then the dry mass was measured. The data were analyzed with STATISTICA 7 software.

Results and discussion

The first sample stand (SP 1) had a tree layer of Norway Spruce (*P. abies*.) with a few single *Prunus avium* L. and *Carpinus betulus* L. The overall canopy cover was 70 %. A shrub layer was not formed. The species *Corylus avellana* L. and *Sambucus nigra* L. had less than 10 % coverage. The total cover of the herbaceous layer was 90 % and consisted of 34 species. *Rubus hirtus* Waldst. et Kit., *Heleborus odorus* Waldst. et Kit. and *Aegopodium podagraria* L. were found more frequently in the mixtoherbosa group. *Galium odoratum* (L.) Scop., *Galium rotundifolium* L. and *Viola*

Fig. 1. Site location.

riviniana Reich. had low coverage. There were young tree saplings of *C. betulus, Juglans regia* L., *Acer pseudoplatanus* L., and *Acer platanoides* L.. *Dactylis glomerata* L. and *Hordelymus europaeus* (L.) Harz. could be found in the group of gramineous grasses, and *Athyrium filix-femina* (L.) Roth and *Dryopteris filix-mas* (L.) Schott. in ferns.

The second sample stand (SP 2) had a dominant tree layer of *P. abies abies,* with single participation of *P. avium.* The canopy cover was 80 %, with no shrub layer. The species *C. avellana* and *Sambucus nigra* had less than 10 % coverage. The herb layer was formed by 48 species with a total cover of 90 %. *G. odoratum*, *Salvia glutinosa* L. and *Sanicula europaea* L. were found more frequently in the mixtoherbosa group. Such species as *Stachys sylvatica* L., *Campanula sparsa* Friv. and *Lamiastrum galeobdolon* (L.) Erend. et Pol. were with low coverage. *A. pseudoplatanus*, *A. platanoides* and *Fagus sylvatica* L. were present, with regrowth of *Fraxinus ornus* L. No edificator undergrowth was observed. *Brachypodium sylvaticum* (Hudson) Beauv., *Festuca drymea* Mert. et Koch and *Hordelymus europaeus* (L.) Harz. could be found in the group of gramineous grasses, and *Carex sylvatica* Hudson in the cyperaceous grasses.

The stand of sample plot (SP 3) had a dominant tree layer of *P. abies*, with single participation of *A. platanoides* and *F. sylvatica*. The canopy cover was 80 %. A shrub layer was not formed. The total cover of the herbaceous layer was 30 % and consisted of 46 plant species. *Mycelis muralis* (L.) Dumort. and *Salvia glutinosa* L. were found more frequently in the mixtoherbosa group. Such species as *Tamus communis* L., *Platanthera bifolia* (L.)L.C. Rich, *Melitis melisophyllum* L., etc. were with low coverage. There were young tree saplings of *A. pseudoplatanus*, *C. betulus*, *Tilia cordata* Miller, *F. sylvatica*, and *Sorbus torminalis* (L.) Crantz. Species as *Poa nemoralis* L. and *F. drymea* could be found in the group of gramineous grasses, and *Luzula sylvatica* (Hudson) Gaudin in the cyperaceous grasses. The cover of the moss layer was about 10 %.

The tree layer on the territory of the sample plot 4 (SP 4) was monodominant and was presented by *P. abies*. The total canopy cover was 70 %. The canopy of the shrub layer was 40 % and such species as *Sambucus nigra* and *C. avellana* could be found more frequently, as well as single finds of *Atropa belladonna* L. and *J. regia*. The coverage of the herbaceous layer was 100 % and consisted of 47 plant species. *S. glutinosa*, *R. hirtus* and *G. odoratum* were found more frequently in the mixtoherbosa group. *Aremonia agrimonoides* (L.) DC, *Circea lutetiana* L., *Geum urbanum* L., etc. had low coverage. There were young tree saplings of *A. platanoides*, *A. pseudoplatanus, Abies alba* Mill., *F. sylvatica,* and *C. betulus.* Species like *D. glomerata* and *P. nemoralis* could be found in the group of gramineous grasses and *C. sylvatica* in the cyperaceous grasses.

P. abies was dominant in the tree layer on the territory of sample plot 5 (SP 5) and *P. avium*, *A. platanoides*, *Alnus glutinosa* (L.) Gaer., and *F. sylvatica* had single participation. The canopy cover was 80 %, with no shrub layer. The species *C. avellana* and *S. nigra* had less than 10 % coverage. The coverage of the herbaceous layer was 80 %, and consisted of 49 plant species. *Asarum europaeum* L., *R. hirtus*, *S. europaea,* and *Geranium robertianum* L. occurred more frequently in the mixtoherbosa group. *Actea spicata* L., *Euphorbia amygdaloides* L. and *Pulmonaria officinalis* L. had low coverage. There were young tree saplings of *A. pseudoplatanus.* Species like *A. filix-femina* and *D. filix-mas* could be found in the group of ferns; *Melica uniflora* Retz. and *F. drymea* in the group of gramineous grasses and *Luzula luzoloides* (Lam.) Dandy in the cyperaceous grasses.

The sixth sample stand (SP 6) had a dominant tree layer of *P. abies*. The canopy cover was 80 %, with no shrub layer. The coverage of herbaceous layer was 80 %, and consisted of 38 plant species. *Oxalis acetosella* L., *R. hirtus*, *Cardamine bulbifera* (L.) Crantz, and *Vaccinium myrtillus* L. were found more frequently in the mixtoherbosa group. *Impatiens noli-tangere* L., *Arum maculatum* L. and *Stellaria nemorum* L. had low coverage. There were young tree saplings of *A. pseudoplatanus, F. sylvatica* and *Sorbus aucuparia* L. *A. filix-femina* and *D. filix-mas* could be found in the group of ferns; *Calamagrostis arundinaceae* (L.) Roth and *P. nemoralis* in the group of gramineous grasses, and *L. luzoloides* in the cyperaceous grasses.

The species determined in the herbaceous layer of the sample plots are presented in Annex 1.

The average phytomass of the herbaceous layer of spruce stands was estimated at 53 $g.m^{-2}$ (Table 2). A comparison between the different understory vegetation groups shows that the mixtoherbosa group was prevailing in all stands. Its stores were highest and varied between 63 % and 95 %. Gramineous grasses were the next significantly presented group: some 4 % of

Annex 1.
Herbaceous layer composition of the investigated spruce stands of EEFE Petrohan.

Sample plot	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6
Abies alba Mill.				+		
Acer platanoides L.	+	+		+		
Acer pseudoplatanus L.	+	+	+	+	+	+
Actaea spicata L.		+			+	
Aegopodium podagraria L.	+	+	+	+	+	
Ajuga genevensis L.	+	+	+	+	+	+
Ajuga reptans L.		+	+	+		
Arctium lappa L.	+		+	+		
Anthriscus sylvestris (L.) Hoffm.					+	
Aremonia agrimonoides (L.) DC.	+		+	+	+	
Arum maculatum L.					+	+
Astrantia major L.						+
Asarum europaeum L.	+	+		+	+	
Athyrium filix-femina (L.) Roth	+	+			+	+
Brachypodium sylvaticum (Hudson) Beauv.						
Bromus tectorum L.					+	
Calamagrostis arundinaceae (L.) Roth						+
Campanula sparsa Friv.		+	+			+
Cardamine bulbifera (L.) Crantz		+	+	+	+	+
Carex sylvatica Hudson		+		+		
Carpinus betulus L.	+		+	+		
Circea luteciana L.	+	+			+	+
Clematis vitalba L.			+	+		
Clinopodium vulgare L.		+	+	+		
Crataegus monogyna Jacq.			+		+	
Cruciata glabra (L.) Ehrend.		+			+	
Corylus avellana L.		+	+		+	
Dactylis glomerata L.	+			+		
Digitalis lanata Ehrh.			+			
Dryopteris filix-mas (L.) Schott.	+	+			+	+
Epilobium montanum L.				+		
Euphorbia amygdaloides L.	+			+	+	
Fagus sylvatica L.	+	+	+	+		+
Festuca drymeja Mert.et Koch	+	+	+	+	+	
Festuca gigantea (L.) Vill.			+			
Fragaria vesca L.		+	+	+	+	
Fraxinus ornus L.		+				
Galium aparine L.					+	
Galium odoratum (L.) Scop.	+	+	+	+	+	+
Galium pseudoaristatum Schur	+		+			
Galium rotundifolium L.		+	+	+		+
Geranium robertianum L.	+			+	+	
Geum urbanum L.				+		
Glechoma hederaceae L.				+	+	
Helleborus odorus Waldst.et Kit.	+					
Hieracium murorum gr.				+		+
Hordelymus europaeus (L.) Harz.	+	+				+
Hypericum perforatum L.		+	+			+

Sample plot	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6
Impatiens noli-tangere L.		+		+	+	
Juglans regia L.	+					
Lamiastrum galeobdolon (L.) Erend.et Pol.	+	+				
Lamium maculatum L.				+		
Lamium purpureum L.					+	
Luzula luzoloides (Lam.) Dandy		+			+	+
Luzula sylvatica (Hudson) Gaudin			+	+		+
Lysimachia nummularia L.			+			
Melica uniflora Retz.	+	+	+		+	
Melitis melissophyllum L.			+			
Mentha longifolia (L.) Hudson					+	
Mercurialis perennis L.	+				+	
Mycelis muralis (L.) Dumort.		+	+	+		+
Myosotis sylvatica Ehrh.ex Hoffm.	+			+	+	
Oxalis acetosella L.		+				+
Physospermum cornubiense (L.) DC					+	
Platanthera bifolia (L.)L.C. Rich		+	+			
Poa nemoralis L.			+	+	+	
Polygonatum verticilatum (L.) All						
Prenanthes purpurea L.		+		+		+
Prunella vulgaris L.		+		+		
Prunus avium L.		+				
Pulmonaria officinalis L.				+	+	
Pulmonaria rubra Schott.			+			
Rubus hirtus Waldst.et Kit.	+	+	+	+	+	+
Rubus idaeus L.	+	+	+		+	+
Salvia glutinosa L.	+	+	+	+	+	
Sambucus racemosa L.						+
Sanicula europaea L.	+	+	+	+	+	
Senecio nemorensis L.		+			+	
Sorbus aucuparia L.		+				+
Sorbus torminalis (L.) Crantz			+			
Stachys sylvatica L.		+	+	+		
Stellaria media (L.) Vill.		+	+	+	+	
Stellaria nemorum L.						+
Symphytum tuberosum L.						+
Tamus communis L.	+	+	+	+	+	
Tanacetum corumbosum				+		
Tanacetum parthenium (L.) Schultz-Bip.					+	
Telekia speciosa (Schreber) Baumg.				+	+	
Tilia cordata Miller	+					
Trifolium medium L.		+				
Urtica dioica L.	+			+	+	
Vaccinium myrtillus L.						+
Veratrum lobelianum Bernh.						
Veronica chamaedrys L.			+			
Veronica officinalis L.		+	+	+	+	
Viola riviniana Reichenb.	+	+	+		+	

the total understory biomass. The young tree saplings were found only in half of the sample plots. They accounted for 14 % of the total amount. The group of ferns (18 %) was found only in two sample plots. Leguminous grasses were the least presented group (0.4 %) and occurred only in one sample plot, as well as the group of cyperaceous grasses (4 %).

The average data obtained for the biomass in this study are congruent with the published data in other similar investigations with the same dominant tree layer. For comparison, the biomass of the herbaceous layer in 70-year-old natural spruce communities with approximately the same tree coverage (80 %) and herbaceous (90 %) layers and at similar altitudes was 51.8 g.m^{-2} (Dimitrova & al. 2014)

No significant correlation and influence was found of the factors: altitude, age of tree layer, exposure, tree layer coverage, shrub layer coverage, herbaceous layer coverage, number of herbaceous species, and biomass storage in the herbaceous layer.

Table 2. Above-ground phytomass (g.m^{-2} a.d.w.) in the herbaceous layer of the investigated spruce stands with averaged values, standard deviations (SD) and standard errors (SE) of the averaged values.

Sample plots / Biological group of herbaceous plants	SP 1 g.m-2	SP 2 g.m-2	SP 3 g.m-2	SP 4 g.m-2	SP 5 g.m-2	SP 6 g.m-2
Mixtoherbosa	72.61	22.01	23.68	41.29	54.365	31.22
Cyperaceous grasses	n.d	n.d	n.d	n.d	n.d	2.17
Leguminous grasses	n.d	0.09	n.d	n.d	n.d	n.d
Ferns	11.93	n.d	n.d	n.d	n.d	12.83
Gramineous grasses	0.7	1.17	1.44	1.43	2.72	n.d
Young tree and bush saplings	30.15	n.d	n.d	4.25	n.d	3.44
Total	**115.39**	**23.27**	**25.12**	**46.97**	**57.085**	**49.66**
SD	17.98	4.29	3.36	10.64	17.07	7.65
SE	3.59	0.86	0.67	2.13	3.41	1.53

Note: *n.d – not determined.

Conclusion

The average phytomass store in the herbaceous layer in the investigated spruce stands was 53 g.m^{-2}. All biological groups of herbaceous plants were present. The mixtoherbosa group had a prevailing biomass store. The highest biomass store was of the mixtoherbosa group. No significant correlation and influence was found of the factors: altitude, age of tree layer, exposure, tree layer coverage, shrub layer coverage, herbaceous layer coverage, number of herbaceous species, and the biomass storage in the herbaceous layer.

The results of these investigations show that the understory of spruce stands is a significant depot of biomass and has to be taken into account while calculating the total biomass storage in forest ecosystems, when evaluating forest biomass models.

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