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BIOMASS OF THE XEROTHERMIC OAK ECOSYSTEM ON A SITE OF COMMUNITY IMPORTANCE, BG0001040 "ZAPADNA STARA PLANINA I PREDBALKAN", BULGARIA

The belowground and aboveground biomass was estimated for the tree story, sprouts and seedling regeneration in a representative Quercus frainetto – Quercus cerris ecosystem on "Zapadna Stara planina i Predbalkan", a Site of Community Importance (SCI). The biomass was measured by destructive sampling (on sample or "model trees" representing three calculated density classes for each species and cut at the stump) of leaves, annual and perennial branches, wood, bark and root components. The belowground (root) biomass was also calculated from a subsample. The data obtained were compared to the results of previous studies and the values on the Bazilevich and Rodin [1971] scale. The ecological status of the forest ecosystem studied and its functional efficiency are discussed based on the study results and specific climate data.

Keywords: *Quercus frainetto – Q. cerris* ecosystem, biomass, SCI, Bulgaria

Introduction

Quercus frainetto-Quercus cerris ecosystems are elements of potential vegetation in Bulgaria and thus contribute to the biological (structural and functional) diversity of Bulgarian forest vegetation, a part of the Illyrian (Balkan) province of the European deciduous forest region. Xerothermic forests belonging to habi-

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tat 91M0 Pannonian – Balkanic turkey oak-sessile oak forests [Kavrakova et al. 2009], which occupy 5% (11042 ha) of the whole territory of the Natura 2000 site: BG0001040 "Zapadna Stara planina i Predbalkan", were studied. This site is the second largest Natura site in Bulgaria, of 219753.26 ha, and it preserves deciduous forest ecosystems a part of beech and oak forests. This habitat is mainly distributed in low mountain and foothill areas and is intensively exploited in Bulgaria; therefore the forests mostly originate from sprouts (coppice reproduction) with impaired ecological and economic functions.

Basic investigations on the aboveground primary production of forest ecosystems in Bulgaria and the Balkan region have been carried out by Melovski et al. [1994]; Grupche et al. [1995] and others. The published data about oak ecosystems functioning in Bulgaria for the period 1985–2009 are cited by Lyubenova [2009].

Studies on the belowground biomass of oak ecosystems in Bulgaria have been published by Lyubenova and Bondev [1987] and Lyubenova [1992]. Mihov [1979] considered the root system biomass of white pine plantations in Bulgaria. Other research has been conducted by Hristovski et al. [2008] in Macedonia; Brumme and Khanna [2009] in European beech ecosystems; and Le Goff and Ottorini [2001] in beech communities in North-East France. Bolte et al. [2004] investigated the belowground plant mass of coarse roots in mixed stands of beech communities. Puhe [2002] studied the plant mass of spruce trees in central Europe. Kurz et al. [1996] obtained data on the root biomass as a considerable carbon depot in the Canadian forest sector. Brunner and Godbold [2007] carried out general research on all aspects of root biomass.

Despite the aforementioned research, the information available on total belowground biomass and on its accumulation of carbon is insufficient. Existing methods for studying belowground biomass are very labor-intensive and often do not provide sufficiently accurate data. For this reason, such data have often been unpublished.

The aim of this study was to estimate the belowground and aboveground biomasses of xerothermic oak ecosystems in the SCI[1] Zapadna Stara planina i Predbalkan, as well as to collect and compare existing data for the ecosystems of interest and to evaluate the habitat function in order to augment previous European investigations, which mainly focused on structure.

[1] SCI (Site of Community Importance) – this is a protected area in European countries which is part of the Natura 2000 network of nature protection areas established by the European Union (EU).

Materials and methods

Inventory of Study Sites

Xerothermic (hot dry) oak ecosystems occupy an elevation range of 0 to 650 m and a slope range from 0 to 40 degrees within the SCI. The largest extent of these ecosystems occurs at an altitude of approx. 300 m and on 15 degree slopes. The *Quercus frainetto-Quercus cerris* (Hungarian or Italian oak – Turkey oak) ecosystems in the study area are of mixed (seed or coppice) origin; only 2% are tall seminal (seed-grown) forests. Using the forest management plan and map for the SCI, polygons in the largest oak forest massifs of the SCI were differentiated, which met the average geographical conditions for distribution (described above). These marked polygons covered 0.6% (1415.4 ha) of the habitat area in the SCI. Four rectangular sampling areas (SAs) or plots of 0.25 ha were then randomly selected from these polygons. All the trees in the tree layer on the four SAs were inventoried. The understory (bush and herb) layers of small trees (at the height of bushes 3–8 m and diameter <10 cm) and different bush species as well as herb species and seedlings of trees and bushes were inventoried on subplots. The site description results and observations describing the SAs are given below.

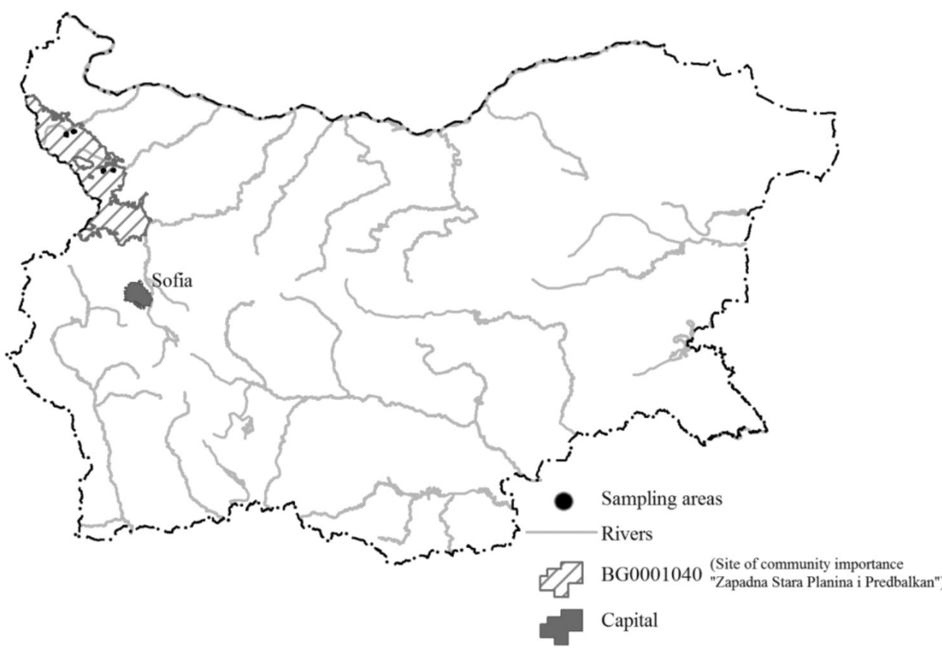

Fig. 1. Location of sampling areas

SA1 was dominated by *Quercus frainetto* Ten. (96.8%). The number of trees in the tree layer was 836 per ha and the total canopy ranged from 0.6 to 0.8 (ocular estimation). The bush layer (less than 10% ocular estimated cover and approx. 3–4 m in height) included four tree species (*Carpinus orientalis* Mill., *Q. frainetto* Ten., *Tilia plathyphyllos* Scop., and *Fraxinus ornus* L.) and eight shrub species. The herb layer had 40–50% coverage and was formed of 29 species, including *Helleborus odorus* Waldst. & Kit., *Carex caryophyllea* Latourr, *Dactylis glomerata* L., *Poa nemoralis* L., and *Lathyrus niger* (L.) Bernh. etc. Dominant tree reproduction from seeds was very good.

SA2 was dominated by *Quercus cerris* L. (58.67% of the total) and *Quercus frainetto* Ten. The total number of trees amounted to 600 per ha. The canopy of tree layer ranged from 0.6–0.9. The bush layer (20% coverage and 7–8 m in height) included 4 trees (*Carpinus betulus* L., *Q. cerris* L., *Sorbus torminalis* (L.) Crantz., *Acer campestre* L.) and nine shrubs. The herb layer had a coverage of 30–40% and included 33 species. The seed regeneration for the dominant oak species was poor but some seedlings such as *Fraxinus ornus* L., *Carpinus orientalis* Miller., and *Sorbus torminalis* (L.) Crantz. were described.

SA3 was dominated by *Quercus cerris* L. and *Quercus frainetto* Ten. with 596 trees per ha, of which 66% were Turkey oak. The canopy of tree layer was 0.6–0.7. The bush layer coverage (average height 7–8 m) was 40% and included six species of tree sprouts – *Crataegus monogyna* Jacq., *Cornus mas* L., *Carpinus orientalis* Miller., *Fraxinus ornus* L., and *Acer campestre* L., and six species of shrubs. The herb layer coverage was 40% and included 31 species. Oak seedling reproduction was poor.

SA4 was dominated by *Quercus frainetto* Ten. There were 668 trees per ha in the tree layer, of which 86% were Turkey oak. The canopy of tree layer ranged from 0.6–0.7. The bush layer coverage was 30% (height 3–4 m) and included tree sprouts of *Q. frainetto* Ten., *Q. cerris* L. and *Fraxinus ornus* L., as well as *Crataegus monogyna* Jacq. and *Cornus mas* L. bushes and 14 other species. The herb layer covered 30–50%, including 33 species with a predominance of *Primula veris* L. and *Astragalus glycyphyllos* L. The dominant trees had good seed reproduction.

Tree biomass measurement

The measurements of the aboveground biomass were carried out using traditional methods from Scandinavian-Russian scientific literature for calculating forest biomass and production [Molchanov et al. 1967; Rodin et al. 1968; Dimitrov 2000; adapted by Lyubenova 2009]. Instead of using biomass equations, this method destructively samples biomass from 1 or more trees of mean species/dimensions, from each of several diameter classes determined by dividing the measured values of the diameters of all the trees in the tree layer of each plot at 4 cm intervals, or by dividing the sum of the cross-sectional areas of the trees (calculated using DBH) in 3 equal sums for three classes of thickness. The total biomass for each diameter class was then obtained by multiplying the biomass of the "mean tree" (according to DBH, height, diameter of crown and habitus), henceforth called the model tree, by the number of trees in each diameter class. This method is presumed more accurate than calculations using biomass equations.

The diameter (DBH) of all the oak trees in the tree layer, their average height and the diameter of their crowns were measured in each SA. Diameter classes for each SA were based on a calculation of the sum of the stem cross-section at 1.3 m (the level of DBH) for *Q. cerris* L. and for *Q. frainetto* Ten. or basal area calculated as $\Sigma[(DBH/2)^2 \cdot 3.14]$. Three diameter classes were defined for each SA by dividing the total basal area of each SA into thirds. This was done by successively summing the single basal area to provide one-third of the total basal area for each thickness class, and the number of trees from the first, second and third classes of thickness was obtained (n1, n2, and n3, where n1 > n2 > n3). The diameter of the first class model tree (DBH1) was calculated as: $\sqrt{[(\Sigma S/3) / (n1 \cdot 3.14)]} \cdot 2$ and likewise for the other two classes. The average height and crown area were also calculated for the trees in each class. Table 1 summarizes these results.

Trees with the average dimension for each diameter class (summarized in table 1) were used to identify a "model tree" or tree of average size for each class and oak species on each SA. There were 18 model trees (the number of Turkey oak trees was under 10% of the total number of all the trees in SA1 and SA4, therefore models were not taken) harvested for their destructive biomass measurement at the end of the growing season (October 2013), when the accumulation of biomass was complete.

The stem of each model tree was divided into 2-m sections. Discs from the middle of the sections were taken to determine the absolute dry weight, and perform a chemical analysis and stem analysis of the growth in height, diameter, volume and weight for the whole period of forest existence. The stem volume was calculated using Huber's formula ($V = \Sigma S \cdot L + V_{is}$, where ΣS is the sum of the circular area of the stem discs, L = 200 cm, and V_{is} – the volume of the last section under 2 m, calculated using the formula for the volume of a cone) [Iliev et al. 1980]. The volume of the bark was calculated as the difference between the volume of the stem with bark and without bark based on the measured diameters of the discs with and without bark. The biomass was calculated using the volumetric (specific gravity conversion) weight of the respective wood and bark samples [Lyubenova 2009]. The wood and bark samples were dried for 48 h at 105°C. The dynamics of the biomass accumulation and stem growth in height during 5-year periods were analysed on the basis of the data obtained through the model trees in the third class of thickness to cover the largest possible period of time. Therefore, the volume and height of the stems were calculated for every 5-year period and then values were averaged for the 3rd class models of Turkish and Italian oak. The resulting diagrams outline the current and future trends in the growth of the forests [Dimitrov 2000; Lyubenova 2009].

Table 1. Summary of inventory data by model trees in sampling areas

SA	No.	Species	DBH Class	QMD [cm]	Mean H [m]	Mean crown D [cm]	Mean crown H [m]	Number of trees per class [n]	Stem [kg]	Annual branches [kg]	Perennial branches [kg]	Acorns [kg]	Leaves [kg]
1	1	Q. frainetto Ten.	1	16.04	15.60	4.60	10.15	117	80.342	0.329	12.928	–	3.459
	2		2	22.55	20.20	6.15	14.42	59	205.214	0.592	65.264	–	5.562
	3		3	30.02	24.00	8.75	16.23	33	576.034	1.549	159.111	–	16.045
2	4	Q. frainetto Ten.	1	17.90	15.80	4.85	11.10	22	95.161	0.299	17.955	–	3.235
	5		2	18.46	18.00	4.30	10.50	21	108.975	0.443	22.681	–	4.470
	6		3	19.43	17.80	5.00	10.95	19	115.521	0.459	22.662	–	4.775
	7	Q. cerris L.	1	18.08	18.80	3.25	12.75	42	143.462	0.194	26.466	0.115	2.212
	8		2	22.46	20.30	4.95	14.50	27	198.552	0.294	37.705	0.075	3.217
	9		3	26.77	21.00	5.70	12.00	19	260.761	0.564	63.604	0.353	4.775
3	10	Q. frainetto Ten.	1	14.66	16.10	3.40	9.10	30	81.869	0.212	12.360	–	3.284
	11		2	24.99	20.75	5.70	12.50	13	276.450	0.783	84.753	–	7.058
	12		3	32.27	24.60	8.25	15.80	8	698.357	1.654	167.930	–	14.134
	13	Q. cerris L.	1	20.02	19.20	5.35	14.70	51	125.822	0.238	20.912	–	1.693
	14		2	27.06	20.80	7.10	13.95	28	253.612	0.516	53.560	0.504	2.529
	15		3	32.75	25.30	9.40	13.15	19	437.585	1.480	161.275	1.061	12.170
4	16	Q. frainetto Ten.	1	17.53	16.00	4.80	9.75	91	82.051	0.364	9.374	–	4.039
	17		2	24.98	20.75	5.95	12.90	45	211.022	0.572	70.895	–	5.704
	18		3	30.03	24.35	7.90	15.00	31	552.702	1.483	161.366	–	14.132

SA – sampling area
DBH – diameter at breast height
QMD – quadratic mean diameter
D – diameter
H – height

The biomass of canopy for each model tree was separated into different fractions for weighing: the perennial branches with different intervals of diameter in the middle, annual branches, and leaves and acorns. These fractions were weighed fresh and subsamples selected to determine the absolute dry weight. The subsamples were dried at 85°C for 48 h (leaves and annual branches) and at 105°C for 48 h (perennial branches and acorns) [Rodin et al. 1968; Lyubenova 2004]. The summary of biomass for all the fractions of each tree is given in table 1.

Understory biomass sampling

For the tree-sprout biomass measurements, 20 stems averaging 6 years of age, having a 2.6 mm diameter in the middle and a height of 14.9 cm were collected for weighing. Age was determined by counting the number of annual rings. The average biomass per stem was multiplied by the number of stems per ha in each SA. The plant number was found using 5 counting plots of 1 m^2.

The herb layer was subsampled in July 2013 by using 10 rectangular 0.25 m^2 subplots in each SA. The herb biomass was fractionated into agro biological groups and seedlings. The same plots were used to count the number of seedlings [Lyubenova 2004].

Belowground biomass sampling

The belowground plant mass (roots) of the tree layer was calculated using a method devised by Rodin et al. [1968] and Winrhizo [2009]. The nutritional area of the tree layer (16 m^2) in SA1 was sampled around the "model tree" in the first class of thickness which was the most numerous in all plots. The average nutritional area was calculated as a ratio of the SA area and number of trees in it. This calculated area did not include the whole root system of the model tree. It was assumed that the share of roots going out from the nutritional area was equal to the roots share entering from the nearby trees [Rodin et al. 1968].

One third of the model nutritional area (3.2 m^2) was separated and fractionated. A pit with a width of 0.5 m and depth of 1.5 m was excavated. The soil horizons were separately collected on tarpaulins; live and dead roots in each horizon were mechanically separated. Live and dead roots were distinguished by color and structure [Vogt et al. 1983]. The live roots were weighed in fractions by diameter classes. The coarse roots were defined in classes of 0.2–1 cm, 1–2 cm, 2–5 cm, 5–10 cm in diameter. No roots were larger than 10 cm in diameter. The root stump and above ground stump were not in nutrition area and so not included in biomass. However the whole oak stump was weighed at 15.90 kg.

The fine roots (under 2 mm in diameter) were not measured. The roots were excavated at a depth of 85 cm (soil horizons: A 0–25 cm, AB 25–60 cm and BC 60–85 cm). The overstory tree and understory plant roots were distinguished according to size, structure and colour.

The root biomass of sprouts was calculated by applying the method of Rodin et al. [1968]. For each of the 20 sprouts, the whole root system was collected, washed and scanned. The images were analysed using the Winrhizo [2009] computer program. Data on the length, mean diameter, and volume of the root system were obtained. The data of root biomass (dried at 85°C and 105°C, the wood parts only, for 48 h) were presented as absolutely dry mass in t ha^{-1} (table 5).

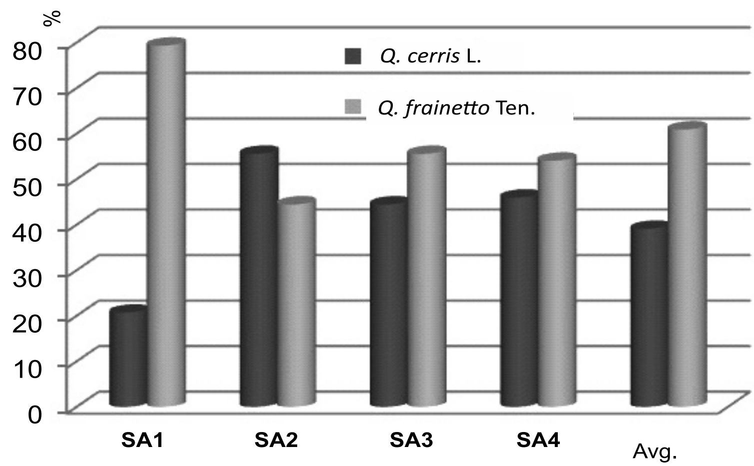

Fig. 2. Ratio between the seedlings of two dominant species by sample areas [%]

Results and discussion

Biomass Per Area Estimates

Based on calculations from the data in table 1 as described above, the average aboveground plant mass of the tree layer was 168 t·ha^{-1}. It varied from approx. 112 t·ha^{-1} for SA2 to 210 t·ha^{-1} for SA1 depending on tree age and total numbers. The percentage of different plant mass in the investigated sample areas is shown in table 2.

Table 2. Aboveground plant mass of the tree layer ($t \cdot ha^{-1}$ absolute dry weight and % of the total mass)

SA №	Trees n·ha-1	Stem			Branches					Branch totals			Leaves	Acorns	Total
		Sum	wood	bark	<1 cm	1–2 cm	2–5 cm	5–10 cm	>10 cm	Peren-nual sum	Annual sum	Sum			
		1	2	3	4	5	6	7	8	9	10	11	12	13	15
1	836	162.067	157.191	4.876	4.428	7.848	19.743	10.435	0.000	42.455	0.498	42.953	5.049	0.000	210.069
%		77.15	74.83	2.32	2.11	3.74	9.40	4.97	0.00	20.21	0.24	20.45	2.40	0.00	100.00
2	600	91.671	89.845	1.826	1.767	3.824	8.123	3.857	0.989	18.560	0.206	18.766	2.105	0.054	112.596
%		81.42	79.79	1.62	1.57	3.40	7.21	3.43	0.88	16.48	0.18	16.67	1.87	0.05	100.00
3	596	133.876	131.325	2.552	3.070	5.892	11.527	8.726	4.571	33.786	0.338	34.124	2.767	0.137	170.905
%		78.33	76.84	1.49	1.80	3.45	6.74	5.11	2.67	19.77	0.20	19.97	1.62	0.08	100.00
4	688	136.386	132.283	4.104	3.808	6.639	16.410	9.325	0.000	36.183	0.419	36.601	4.249	0.000	177.237
%		76.95	74.64	2.32	2.15	3.75	9.26	5.26	0.00	20.41	0.24	20.65	2.40	0.00	100.00
Avg.		131.000	127.661	3.339	3.268	6.051	13.951	8.086	1.390	32.746	0.365	33.111	3.542	0.048	167.702
%		78.12	76.12	1.99	1.95	3.61	8.32	4.82	0.83	19.53	0.22	19.74	2.11	0.03	100.00

SA – sampling area

The average total biomass in the herb layer was approx. 48.6 g·m^{-2} varying from lower values in SA1 and SA3 to higher ones in SA2 and SA3 when compared to the average value (table 3). The average share of grasses within the total herb biomass was 36.7%, even in the two of sample areas (SA3 and SA2) it was 57% and 47% respectively, which showed the turfing tendency of these forests. This has had a negative impact on the number of seedlings and their survival. The mean number of seedlings for all the sample areas was 91 per m^{-2} with an average age of 2 years. It varied among the SAs from 148 and 116 (for SA4 and SA1) to 36 per m^2 (SA2 and SA3). In three SAs, seedlings of *Q. frainetto* dominated, most strongly in SA1, and *Q. cerris* seedlings dominated only in SA2 (fig. 2). The average biomass of the seedlings was 8.5 g·m^{-2} or 17.6% of the total biomass of the herb layer and was largest in SA3 (11.3 g·m^{-2} or 29.6% of the total herb layer mass in SA3), followed by SA1 (9.5 g·m^{-2}, 28.2%). The biomass of the seedlings in SA2 was only 3 g·m^{-2} or 6% of the total mass in the herb layer, which was the lowest obtained value (table 3). As a whole, seedlings in the four sample areas were in a good ecological state: no withering or yellowing at an average age of 2 years was observed.

All the average values (X) obtained for the herb layer biomass fractions were representative as ratio X/Sx was larger than the Student's coefficient (t) at $\alpha = 0.05$ for the 4 sampled areas (t = 2.132 for n = 4).

Table 3. Aboveground herb layer plant mass (g·m^{-2} absolute dry weight and % of the total mass)

SA/Groups	Grasses	Legumes	Mixed herbs	Seedlings of trees	Dead mass	Total
1	2.976	17.158	3.521	9.544	0.676	33.875
%	8.8	50.7	10.4	28.2	2.0	100.0
2	23.471	2.768	11.432	3.009	8.880	49.560
%	47.4	5.6	23.1	6.1	17.9	100.0
3	21.704	0.000	4.668	11.269	0.417	38.058
%	57.0	0.0	12.3	29.6	1,1	100.0
4	22.119	0.000	32.533	10.326	7.762	72.740
%	30.4	0.0	44.7	14.2	10.7	100.0
Average, X	17.568	4.982	13.039	8.537	4.434	48.558
%	36.2	10.3	26.9	17.6	9.1	100.0
St.Dev., S	9.757	8.222	13.457	3.752	4.513	17.432
Error of X, Sx	2.439	2.055	3.364	0.938	1.128	4.358
*X/Sx > **t	7.202	2.424	3.876	9.101	3.930	11.142

*Representativeness of X - X/Sx > 2.132 for all fractions
**Student's coefficient, t = 2.132 for α = 0.05 and n = 4
SA – sampling area
X – mean value
St.Dev. – standart deviation

The average number of sprouts was 22.4 per m^2; 85% of the sprouts were Italian oak. The mean biomass of the sprouts was calculated as 50.938 $g \cdot m^{-2}$ (table 4). It was distributed in 40% of the overground biomass and 60% of the belowground (root) system. The annual (new) growth of the three layer was approx. 15% and the perennial (remaining) comprised approx. 25%. The average root diameter equaled 0.828 mm, the length was 2908.774 $cm \cdot m^{-3}$, and the volume was 14.784 cm^3.

Table 4. Mass of tree sprouts ($g \cdot m^{-2}$ absolute dry weight and % of the total mass)

Fraction	Aboveground			Belowground						Total [$g \cdot m^{-2}$]
	stem and perenual branches [$g \cdot m^{-2}$]	leaves and annual branches [$g \cdot m^{-2}$]	sum [$g \cdot m^{-2}$]	roots [$g \cdot m^{-2}$]	S [cm^2]	S roots [cm^2]	d aveg. [mm]	l/V [$cm \cdot m^3$]	V [cm^3]	
	12.902	7.549	20.429	30.509	117.239	742.941	0.828	2908.774	14.784	50.938
%	25.33	14.82	40.15	59.85	–	–	–	–	–	100.00

S – area
d – diameter
V – volume

Table 5. Belowground plant mass ($t \cdot ha^{-1}$ absolute dry weight)

Soil horizon	Living roots, d [cm]					Dead roots	Total
	0.2–1	1–2	2–5	5–10	Sum		
A	16.640	12.190	28.430	7.810	65.070	5.430	70.500
AB	7.290	1.250	24.060	0.000	32.600	3.460	36.060
BC	2.190	3.130	4.370	0.000	9.690	0.010	9.690
Total	26.120	16.560	56.870	7.810	107,36	8.900	116.250

d – diameter

The root biomass was equal to 116 $t \cdot ha^{-1}$ (table 5, fig. 3). Of the root system, 7.7% was dead mass. In the distribution of belowground biomass, the largest amount (60.65%) of the total was located in the upper (0–25 cm) layer of the soil. The largest amount of the root mass (48.92%) was at a diameter of 2–5 cm. The smallest amount (6.72%.) was at a diameter of 5–10 cm.

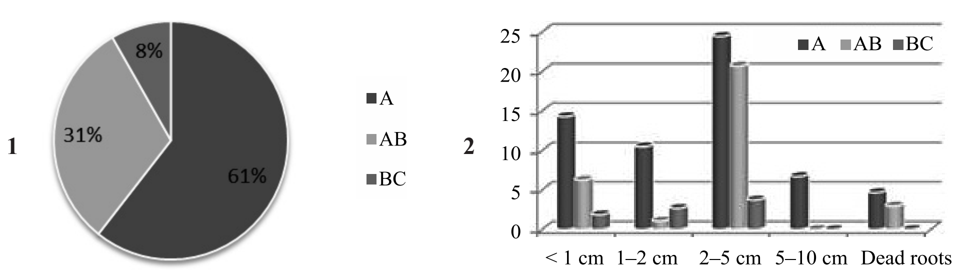

Fig. 3. Ratio of root biomass [%]: 1 – by soil horizons; 2 – by fractions

Comparison to Other Studies

The results for coarse root stocks obtained in the present study were compared to those reported by other authors for the same tree species and other forest ecosystems. The differences are probably due to variations in the ecological conditions and stand characteristics of the SAs and in the methodologies. Biomass numbers in this study are greater than those presented by Lyubenova and Bondev [1987] who reported a coarse root biomass of 68 t·ha^{-1} for *Quercus frainetto* + *Quercus cerris – Festuca heterophylla* + *Poa nemoralis community* in Sofia region, Bulgaria.

The root biomass results were also compared to other forest ecosystems. For example, the established coarse root biomass from beech communities in Macedonia, with a mean diameter 16 cm [Hristovski et al. 2008], developed on *Distric Cambisols*, at an elevation of 1400 m and with a stand density of 1200 trees per ha was 45 t·ha^{-1}. The coarse root biomass for beech communities in Germany aged 40–79 years was estimated at 54–48 t·ha^{-1} [Brumme, Khanna 2009]. The coarse root biomass of Scot's pine forest stands in Yundola (Bulgaria) studied by Mihov [1979] at 110 years of age, with a diameter of 28 cm, a height of 26 m and a density of 600 trees per ha was 26–105 kg per model tree.

The total plant mass of the oak ecosystems studied equaled from 301 to 477 t·ha^{-1}. The largest part of the plant mass was in the aboveground component and equaled 170.985 t·ha^{-1} (fig. 4). Some (98%) of the aboveground plant mass was in the over story. Very small amounts (1.42 and 0.50%, respectively) were in the sprout and seedling biomass.

Fig. 4. Average distribution [%] of total plant mass: A – by spheres of community; B – by plant mass fractions

The data on plant mass for the investigated xerothermic forest vegetation were close to those published by other researchers (table 6). The cited references give information about the amount of biomass of xerothermic forest vegetation in terms of the respective geographical coordinates, soils, species composition, age of forests and husbandry practices.

Table 6. Published data for xerothermic oak vegetation plant mass

№ of publ.	Avg. Temp., [°C]	Avg. Precip., [mm]	Altitude, [m]	Aspect	Elevation, 0	Soil	Origin	Avg. age, Y	Canopy	Avg. DBH, [cm]	Avg. H, [m]	Overgr. BM, [t·ha^{-1}]	Tree storey BM, [t·ha^{-1}]	Undergr. BM, [t·ha^{-1}]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lyubenova, Bondev [1998]*	10.2	603	150	E	3.0	Umbric cambisols	shoots	52.3	0.7	13.0	15.3	–	343.5	–
Bondev et al. [1998]*	12.5	650	50	NW	5.0	Chromic Luvisols	shoots	48.0	0.7	15.4	13.7	349.1	91.6	–
	12.5	650	50	NW	1.0	Chromic Luvisols	shoots	48.0	0.7	13.1	13.8	–	112.5	–
Lyubenova [1996]*	12.0	567	300	NW	–	Chromic lLuvisols	shoots	56.5	0.9	15.7	13.5	–	181.0	–
Lyubenova, Bondev [1998]*	11.1	615	400	NE	–	District planosols	shoots	53.0	0.7	17.0	19.0	119.9	–	–
	11.1	688	400	NE	–	District planosols	shoots	43.0	0.8	18.0	18.0	431.3	–	–
	11.1	578	400	W	–	District planosols	shoots	65.0	0.8	20.0	20.0	233.0	–	1.2
	11.1	–	400	W	–	District planosols	seminal	125.0	0.7	25.0	25.0	342.0	–	68.3
Bondev, Lyubenova [1992]*	8.0	627	950	W	–	Alisols	–	45.0	–	–	–	–	–	–
Lyubenova, Bondev [1987]*	–	–	–	S	–	Planosols	–	53.0	0.8	–	–	–	–	–
Meshinev, Nikolov [1986]	10.0	700	300	S	18.0	Planosols	shoots	–	0.7	–	–	13.5	8.0	–
Lyubenova, Sazdov [1995]*	11.3	615	–	SW	–	Planosols	shoots	65.0	0.7	–	–	–	3.6	–
Lyubenova [1996]*	11.3	578	150	W	–	Chromic cambisols	seminal	43.0	0.8	25.0	25.0	341.9	341.7	–
	11.3	578	150	N	–	Luvisols	shoots	41.0	0.8	20.0	20.0	233.0	232.6	–

Table 6. Continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lyubenova [1995b]*	10.6	644	1040	E	8.0	Luvisols	shoots	95.0	0.8	14.0	12.0	–	–	–
Lyubenova [1995]*	10.9	688	290	E	2.0	Cambisols	shoots	–	0.8	18.0	18.0	430.2	451.3	–
Lyubenova, Dimova [2000]*	10.0	882	1500	E	27.5	Chromic Luvisols	seminal	45.0	–	50.0	35.0	–	–	–
Grupche et al. [1993]	10.0	753	900	–	–	Gray Luvisols	–	53.0	0.7	–	–	229.9	451.4	–
Lyubenova et al. [1996]*	10.4	–	475	–	–	–	–	9.0	0.7	13.0	15.0	121.6	119.7	–
Lyubenova [1995]	12.9	832		–	–	–	–	10.0	–	16.5	19.0	119.7	102.2	–
Melovski et al. [1994]	12.9	467	350	–	10.0	–	–	15.0	–	3.0	2.5	8.5	2.3	–
	12.9	467	350	–	10.0	–	–	42.0	–	5.0	3.5	4.8	1.7	–
	–	467	350	–	10.0	–	–	42.0	0.7	3.5	2.0	7.9	2.4	–
Lalova [1994]	–	–	480	–	–	–	shoots	42.0	0.7	21.0	19.4	47.0	–	–
	–	–	480	–	–	Luvisols	shoots	42.0	0.7	21.4	19.6	–	–	–
	–	–	200	–	–	Planosol	shoots	30.0	0.7	28.4	22.7	231.5	–	47.6
	–	–	–	–	–	Chrom. Cambisol	shoots	40.0	0.9	35.0	20.9	279.0	–	85.4
Ninov [1995]	–	–	–	–	–	Umbric Leptosol	shoots	31.0	0.9	–	7.0	157.6	–	56.7
	–	–	–	–	–	Lithic Leptosol	shoots	34.0	0.9	–	13.0	190.6	–	51.2
	–	–	–	–	–	Luvisols	shoots	32.0	0.8	–	8.0	113.8	1.8	20.9
	–	–	480	NE	–	–	shoots	42.5	0.5	–	7.0	90.7	4.1	–
	–	–	–	W	–	–	shoots	–	–	–	4.0	51.3	–	–
Lalova [1994]	–	–	–	S	–	–	shoots	–	–	–	–	279.0	–	–
Gateva [1994]	–	–	–	N	–	–	shoots	–	–	–	–	–	401.0	–

* by Lyubenova [2009]; DBH – diameter at breast height; H – height; BM – biomass

The analysis of tree growth (using data collected from the 2-m stem wood sections) for the 3rd diameter class at 70 years of age showed that the growth accumulation of the stem biomass of Italian oak and Turkey oak was still intensive, i.e. the curves had not plateaued (fig. 5A, 5B). Since the trees examined from the third density class were only approx.16% of the total trees in the tree layer, and those from the first and second density classes were younger, it may be concluded that the forest has not exhausted its productive possibilities in spite of its coppice character and intensive exploitation in the recent past. The wood accumulation was sufficiently described with 2nd and 3rd degree polynomials and with respective mathematical equations for Italian and Turkish oak, which could be used for approximate evaluations because the productive behaviour of coppice forests is different from that of seminal ones. The stem growth in height (fig. 5C, 5D) could be described by 4th and 6th degree polynomials and respective mathematical equations. Height growth plateaued at approx. 30–35 years of age.

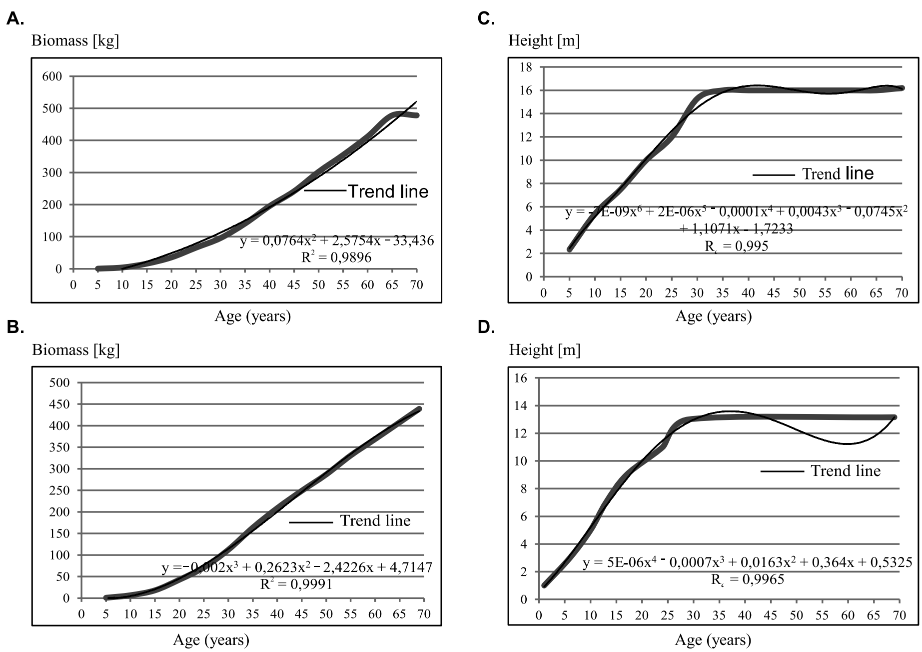

Fig. 5. Dynamics of stem growth: biomass accumulation (kg) for Italian oak (A) / Turkey oak (B); growth in height (m) for Italian oak (C) / Turkey oak (D)

Conclusion

According to the biomass data collected, the studied xerothermic forest vegetation would be given a rating of 8 (300.1–400 t·ha^{-1}) on the Bazilevich and Rodin scale [1971] for broad-leaved forest ecosystems. The plant mass distribution of the aboveground perennial stems and leaves were in the range of other cited data: 60–81% and 1–3%. The estimated percentage of the belowground biomass was higher than the cited data (17–29%). This could be due to the coppice character of the forests. Offshoots utilize the powerful maternal root systems. Although the majority of the roots die because young shoots cannot produce enough assimilates, it is assumed that in coppice forests the quantities of belowground plant mass is higher compared to seminal forests of the same species. But the differences may be due to the efforts of the authors to more accurately measure the belowground biomass with existing labour-intensive methods. The amount of bush and herb layer biomass, belowground biomass and the change of soil status probably exerted an influence on the seed regrowth of these communities. The study area was experiencing having some problems transforming from coppice tree communities into seed-produced forest, despite the large number of seedlings. Because of the high death-rate of seedlings at young and middle age, the number of sprouts was low as shown by the differences in age and number of seedlings and sprouts, and the existing tendency of tuffing in the herb layer. The changed soil characteristics from a possibly higher rate of dead root mass in the initial stages of coppice forest development may also have caused the high death-rate of seedlings at young and middle age. Nevertheless, these forests have vital potential for biomass production and seedling reproduction. Under good management, these communities should improve their health as well as their ecological, social and economic importance. This new data has helped to complete the biomass database for these human-influenced forests in southern Europe, may be used for management, future comparisons and conclusions, and may contribute to an understanding of the real productive capacity of oak forest-habitats and their potential contribution to European habitat diversity.

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