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Above-Ground Biomass of Black Locust *(Robinia pseudoacacia* L.*)* Trees and Stands

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Abstract – The increasing demand for forest products, diminishing forest land areas, and general concern about the long-term effects of deforestation have increased the need for multipurpose tree species with rapid growth rates. Consequently, information on renewable energy resources is becoming increasingly crucial, and forest biomass determination is becoming a significant part of forestry. Black locust (*Robinia pseudoacacia* L.) is a fast growing, nitrogen fixing, stress tolerant species with durable and high quality wood that can be used for many purposes including wall panelling; vine props; furniture; pulp and paper; animal feed stock; bee forage; and biomass energy. This article presents the above-ground biomass of black locust, both for individual trees and for stands. Information concerning wet and absolute dry wood for stem, merchantable ($d_{1.3}$ > 5 cm) and small ($d_{1.3}$ < 5 cm) wood, and for other tree parts (foliage, bark) for individual trees and for black locust stands are detailed in dendromass tables by six yield classes.

black locust / *Robinia pseudoacacia* L. / forest biomass / dendromass

Kivonat – Akác (Robinia pseudoacacia) fák és faállományok föld feletti biomasszája. Az erdészeti termékek iránti növekvő kereslet, a csökkenő erdőterületek és az erdőirtás hosszú távú hatásai miatti általános aggodalom megnövelte a gyors növekedésű, többcélú fafajok iránti igényt. Tehát a megújítható erdei energiaforrásokra vonatkozó információk egyre fontosabbak, ennélfogva az erdei biomassza meghatározása fontos részévé válik az erdőgazdálkodásnak. Az akác (*Robinia pseudoacacia* L.) egy gyorsan növő, nitrogénmegkötő, stressztűrő faj, mely számos célra alkalmas (lambéria, szőlőkaró, bútor, cellulóz és papír, állati takarmány, méhlegelő és biomassza energia), tartós és jó minőségű faanyaggal rendelkezik. Jelen tanulmány az akác faegyedek és állományok föld feletti biomasszáját mutatja be. Nedves és abszolút száraz törzsre, vastag ($d_{1,3}$ > 5 cm) és vékony fára ($d_{1,3}$ < 5 cm) és a fák egyéb részeire (levél, kéreg) vonatkozóan, az egyes fák, illetve állományok adatait szemlélteti dendromassza táblázatokban, hat fatermési osztályba sorolva.

fehér akác / *Robinia pseudoacacia* L. / erdei biomassza / dendromassza

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1 INTRODUCTION

Between 1610 and 1620, black locust (*Robinia pseudoacacia* L.) became the first forest tree species imported to Europe (France) from North America (Bartha 2016). Since then, the species has experienced periodic vicissitudes in terms of interest and enthusiasm for its cultivation and utilization. Over the last twenty years, interest in the species has grown in an increasing number of countries. The reasons for this are as follows: (1) the energy crisis has stimulated research into fast growing, nitrogen-fixing trees such as black locust and has introduced new growing techniques (Short Rotation Forestry) for them; (2) countries such as Hungary, Romania, France, Slovakia, Bulgaria, Korea, and China are vigorously developing the species; (3) from both practical and biological research standpoints, the species has many desirable characteristics (durable wood, easy regeneration); (4) the species is resilient to climate change and air pollution.

Forest biomass (dendromass) is fundamentally different from other forms of biomass such as agricultural biomass. In this paper, we employ the following definitions: *Dendromass:* the total organic production of the trees in forest stands including foliage and volume of stumps and roots (above-ground dendromass lacks the latter components). Forest growing stock, which is the above-ground total volume without leaves in broadleaved stands and with needles in coniferous stands, provides an overwhelming portion of biomass. We use above-ground volume and biomass in this study.

This study aims to provide data on the above-ground biomass of black locust trees and stands.

2 MATERIALS AND METHODS

To investigate the structural distribution of the above-ground biomass of black locust in Hungary, we took detailed measurements of 65 trees of different origins, ages, and diameters ranging from 7 cm to 35 cm, with the average diameter being 18.6 cm. We separated the trees into height and growing space classes. Detailed measurements were taken for data on stem volume, merchantable wood and small wood volume, and other tree parts. Using these data, different biomass components can be accurately determined. The data is summarised in a table containing the following entries:

1. tree number,
2. height class,
3. growing space class,
4. breast height diameter (cm),
5. tree height (m),
6. crown proportion (%),
7. merchantable volume (diameter > 5 cm) (volume over and under bark) (m^3),
8. stem volume (m^3),
9. small (unmerchantable) wood volume (diameter < 5 cm) (m^3),
10. above-ground total volume (7+9) (volume over and under bark) (m^3),
11. bark volume (m^3),
12. raw foliage volume (m^3),
13. green mass of merchantable wood (kg),
14. green mass of unmerchantable wood (kg),
15. green mass of above ground total volume (kg),
16. green mass of the raw foliage (kg),
17. mass of bark (kg),

18. bulk density of the merchantable volume under bark (kg/m^3),
19. bulk density of unmerchantable volume over bark (kg/m^3)
20. bulk density of raw foliage without bark (kg/m^3)

We used stem analysis in 2 m sections to determine merchantable volume. We determined small wood volume by water displacement, and green foliage and mass data with weight measurement. In addition to our data, we utilized the data and research results of Fekete (1937) and Sopp (1974) to determine bark proportion. The green bulk density (green mass divided by volume) of the black locust trees we investigated was

merchantable volume: $\rho_{wetmerch} = 971$ kg/m^3,
small wood volume: $\rho_{wetunmerch} = 913$ kg/m^3.

Absolute dry bulk density based on laboratory measurements:

merchantable volume: $\rho_{drymerch} = 727$ kg/m^3,
unmerchantable volume: $\rho_{dryunmerch} = 700$ kg/m^3.

3 RESULTS

There are several approaches to determine foliage biomass. One approach determines the entire crown biomass including branches. Another method determines the biomass of foliage and branch components separately. Using these data, we can develop relationships to estimate raw foliage mass in terms of various tree parameters (breast height diameter, tree height etc.). In this study, we treated foliage as a separate biomass component, and ascertained its mass as a function of breast height diameter. We used the mass data of foliage specified in the materials and methods section. The following linear regression was fitted to the data:

$$m_{wetfoliage} = -2.25130 + 0.68785 \times d_{1,3},$$

where:

$m_{wetfoliage}$ = green foliage biomass,
r^2 = 0.811. In addition to green foliage mass, we calculated the absolute dry mass of foliage.

Green volume, green mass and absolute dry mass of foliage are shown as a function of breast height diameter in *Table 1*. In addition to breast height diameter, foliage weight is also influenced by other factors (crown closure, height class of the tree, genetic factors, etc.). Previous studies also found breast height diameter as the most reliable estimator of foliage mass. In addition to our data, we also used those of Sopp (1974) to estimate bark volume.

We prepared a mass table for black locust *(Table 2)* providing *the mass in green and absolute dry state of single trees* by merchantable and small wood, the foliage mass and total mass in green and absolute dry state. The table is based on the following equations (equation form and independent variables are based on Forress (1969)):

Merchantable volume $v_{merch} = 0.09236 - 0.00076871 \times d_{1.3} + 0.0027454 \times h + + 0.00037522 \times d_{1.3}^2 + 0.000024513 \times h \times d_{1.3}^2 - - 0.020365 \times \ln(h \times d_{1.3}^2)$

Total volume $v_{total} = 0.066731 + 0.0016704 \times d_{1.3} + 0.001685897 \times h + + 0.00038029 \times d_{1.3}^2 + 0.000024291 \times h \times d_{1.3}^2 - - 0.016587 \times \ln(h \times d_{1.3}^2)$

Unmerchantable volume $v_{unmerch} = v_{tot} - v_{merch}$

Wet merchantable mass $m_{wetmerch} = v_{merch} \times \rho_{wetmerch}$

Wet unmerchantable mass $m_{wetunmrch} = v_{unmerch} \times \rho_{wetunmerch}$

Wet total mass	$m_{wettotal}$	$= m_{wetunmrch} + m_{wetmerch}$
Dry merchantable mass	$m_{drymerch}$	$= v_{merch} \times \rho_{drymerch}$
Dry unmerchantable mass	$m_{dryunmrch}$	$= v_{unmerch} \times \rho_{dryunmerch}$
Dry total mass	$m_{drytotal}$	$= m_{dryunmrch} + m_{drymerch}$
Wet foliage mass	$m_{wetfoliage}$	$= -2.25130 + 0.68785 \times d_{1,3}$
Dry foliage mass	$m_{dryfoliage}$	$= m_{wetfoliage} \times 0.52874$
Wet total mass	$m_{wettotal}$	$= m_{wettotal} + m_{wetfoliage}$
Dry total mass	$m_{drytotal}$	$= m_{drytotal} + m_{dryfoliage}$

Table 1. Black locust single tree foliage volume and mass as a function of breast height diameter (DBH)

DBH	Raw green volume of foliage	Mass of foliage		DBH	Raw green volume of foliage	Mass of foliage	
		Raw green	Absol. dry			Raw green	Absol. dry
(cm)	(m^3)	(t)		(cm)	(m^3)	(t)	
4	0.0006	0.0005	0.0001	**23**	0.0192	0.0136	0.0035
5	0.0016	0.0012	0.0003	**24**	0.0261	0.0142	0.0037
6	0.0026	0.0019	0.0005	**25**	0.0211	0.0149	0.0039
7	0.0036	0.0026	0.0007	**26**	0.0221	0.0156	0.0040
8	0.0045	0.0032	0.0008	**27**	0.0231	0.0163	0.0042
9	0.0055	0.0039	0.0010	**28**	0.0241	0.0170	0.0044
10	0.0065	0.0046	0.0012	**29**	0.0251	0.0177	0.0046
11	0.0075	0.0053	0.0014	**30**	0.0261	0.0184	0.0048
12	0.0085	0.0060	0.0016	**31**	0.0270	0.0191	0.0050
13	0.0095	0.0067	0.0017	**32**	0.0279	0.0197	0.0051
14	0.0105	0.0074	0.0019	**33**	0.0289	0.0204	0.0053
15	0.0114	0.0081	0.0021	**34**	0.0299	0.0211	0.0055
16	0.0123	0.0087	0.0023	**35**	0.0309	0.0218	0.0057
17	0.0133	0.0094	0.0025	**36**	0.0319	0.0225	0.0058
18	0.0143	0.0101	0.0026	**37**	0.0329	0.0232	0.0060
19	0.0153	0.0108	0.0028	**38**	0.0339	0.0239	0.0062
20	0.0163	0.0115	0.0030	**39**	0.0348	0.0246	0.0064
21	0.0173	0.0122	0.0032	**40**	0.0358	0.0252	0.0065
22	0.0183	0.0129	0.0033				

Using single tree dendromass data, we analysed the *above-ground dendromass of black locust stands* by using the mass table for the average tree for each entry in the yield table. As a basis, we used the Hungarian black locust yield table by Rédei (1984).

In *Table 3*, we present the volume of black locust by small wood volume and merchantable volume; foliage green volume; absolute dry above-ground mass of small wood volume, merchantable and total volume; mass of foliage; and total dendromass for the first three yield classes of the yield table. The ratio of small wood volume and merchantable volume was based on Burján (1976). The figures presented are for the total stand. The values in the table are good estimates of the composition and mass of the above-ground dendromass of black locust stands.

Table 2. Above-ground mass in wet and absolute dry state of black locust single trees

$d_{1,3}$	h	Volume (m^3)			Mass wet (kg)			Mass dry (kg)			Foliage mass (kg)		Total mass (kg)	
(cm)	(m)	unmerch.	merch.	total	unmerch.	merch.	total	unmerch.	merch.	total	wet	dry	wet	dry
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
8	6	0.010	0.015	0.025	9.352	14.493	23.845	7.171	10.851	18.021	3.3	0.8	27.097	18.853
8	7	0.010	0.016	0.026	8.904	15.634	24.537	6.826	11.705	18.532	3.3	0.8	27.789	19.364
8	8	0.009	0.018	0.027	8.384	17.182	25.566	6.428	12.865	19.292	3.3	0.8	28.818	20.124
9	7	0.013	0.020	0.033	11.997	19.255	31.253	9.199	14.417	23.615	3.9	1.0	35.192	24.629
9	8	0.013	0.022	0.034	11.474	21.209	32.683	8.797	15.879	24.676	3.9	1.0	36.622	25.690
9	9	0.012	0.024	0.036	10.897	23.473	34.370	8.354	17.575	25.929	3.9	1.0	38.309	26.943
10	8	0.016	0.028	0.044	14.485	26.836	41.321	11.106	20.092	31.198	4.6	1.2	45.948	32.394
10	9	0.015	0.030	0.046	13.903	29.553	43.456	10.660	22.127	32.786	4.6	1.2	48.083	33.982
10	10	0.015	0.033	0.048	13.279	32.515	45.795	10.181	24.345	34.526	4.6	1.2	50.422	35.722
11	8	0.019	0.035	0.054	17.432	33.970	51.402	13.365	25.434	38.799	5.3	1.4	56.717	40.177
11	9	0.018	0.038	0.057	16.847	37.187	54.033	12.916	27.842	40.759	5.3	1.4	59.348	42.137
11	10	0.018	0.042	0.060	16.218	40.649	56.867	12.434	30.435	42.869	5.3	1.4	62.182	44.247
11	11	0.017	0.046	0.063	15.555	44.310	59.865	11.926	33.176	45.102	5.3	1.4	65.180	46.480
12	9	0.022	0.048	0.069	19.738	46.306	66.044	15.133	34.670	49.803	6.0	1.6	72.047	51.363
12	10	0.021	0.052	0.073	19.105	50.316	69.421	14.648	37.672	52.320	6.0	1.6	75.424	53.880
12	11	0.020	0.056	0.076	18.437	54.525	72.962	14.136	40.823	54.959	6.0	1.6	78.965	56.519
12	12	0.019	0.061	0.080	17.741	58.897	76.638	13.602	44.097	57.699	6.0	1.6	82.641	59.259
13	10	0.024	0.063	0.087	21.949	61.463	83.412	16.828	46.018	62.847	6.7	1.7	90.103	64.589
13	11	0.023	0.068	0.092	21.276	66.267	87.543	16.313	49.615	65.927	6.7	1.7	94.234	67.669
13	12	0.023	0.073	0.096	20.575	71.234	91.809	15.775	53.334	69.109	6.7	1.7	98.500	70.851
13	13	0.022	0.079	0.100	19.849	76.340	96.189	15.218	57.157	72.375	6.7	1.7	102.880	74.117
14	11	0.026	0.082	0.108	24.079	79.496	103.575	18.462	59.519	77.981	7.4	1.9	110.953	79.905
14	12	0.026	0.088	0.113	23.372	85.106	108.478	17.919	63.720	81.640	7.4	1.9	115.857	83.564
14	13	0.025	0.094	0.118	22.641	90.854	113.495	17.359	68.024	85.383	7.4	1.9	120.874	87.307
14	14	0.024	0.100	0.124	21.890	96.720	118.610	16.783	72.415	89.198	7.4	1.9	125.988	91.122
15	12	0.029	0.103	0.132	26.139	100.480	126.619	20.041	75.231	95.271	8.1	2.1	134.685	97.377
15	13	0.028	0.110	0.138	25.402	106.919	132.320	19.476	80.051	99.527	8.1	2.1	140.387	101.633
15	14	0.027	0.117	0.144	24.644	113.474	138.119	18.895	84.960	103.855	8.1	2.1	146.185	105.961

Table 2 continued

$d_{1,3}$	h	Volume (m^3)			Mass wet (kg)			Mass dry (kg)			Foliage mass (kg)		Total mass (kg)	
(cm)	(m)	unmerch.	merch.	total	unmerch.	merch.	total	unmerch.	merch.	total	wet	dry	wet	dry
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	12	0.032	0.121	0.152	28.879	117.330	146.209	22.142	87.847	109.988	8.8	2.3	154.963	112.250
16	13	0.031	0.128	0.159	28.136	124.507	152.642	21.572	93.220	114.791	8.8	2.3	161.397	117.053
16	14	0.030	0.136	0.166	27.372	131.800	159.172	20.986	98.681	119.667	8.8	2.3	167.927	121.929
16	15	0.029	0.143	0.172	26.591	139.195	165.786	20.387	104.217	124.604	8.8	2.3	174.540	126.866
17	13	0.034	0.148	0.182	30.847	143.597	174.444	23.650	107.513	131.163	9.4	2.4	183.886	133.607
17	14	0.033	0.156	0.189	30.076	151.676	181.752	23.060	113.562	136.621	9.4	2.4	191.195	139.065
17	15	0.032	0.165	0.197	29.289	159.856	189.145	22.456	119.686	142.142	9.4	2.4	198.587	144.586
18	14	0.036	0.178	0.214	32.760	173.084	205.844	25.118	129.590	154.708	10.1	2.6	215.974	157.334
18	15	0.035	0.188	0.223	31.965	182.097	214.063	24.508	136.339	160.847	10.1	2.6	224.193	163.473
18	16	0.034	0.197	0.231	31.155	191.199	222.354	23.887	143.153	167.040	10.1	2.6	232.484	169.666
19	14	0.039	0.202	0.241	35.427	196.009	231.436	27.162	146.755	173.916	10.8	2.8	242.254	176.724
19	15	0.038	0.212	0.250	34.624	205.903	240.528	26.546	154.162	180.709	10.8	2.8	251.345	183.517
19	16	0.037	0.222	0.259	33.806	215.886	249.692	25.919	161.636	187.556	10.8	2.8	260.510	190.364
19	17	0.036	0.233	0.269	32.975	225.945	258.920	25.282	169.168	194.450	10.8	2.8	269.738	197.258
20	15	0.041	0.238	0.279	37.267	231.262	268.529	28.573	173.149	201.721	11.5	3.0	280.035	204.711
20	16	0.040	0.249	0.289	36.441	242.172	278.614	27.940	181.317	209.257	11.5	3.0	290.119	212.247
20	17	0.039	0.261	0.300	35.602	253.160	288.762	27.296	189.544	216.840	11.5	3.0	300.268	219.830
20	18	0.038	0.272	0.310	34.751	264.216	298.967	26.644	197.822	224.466	11.5	3.0	310.473	227.456
21	15	0.044	0.266	0.310	39.896	258.162	298.058	30.588	193.289	223.877	12.2	3.2	310.251	227.049
21	16	0.043	0.278	0.321	39.062	270.048	309.110	29.949	202.189	232.137	12.2	3.2	321.304	235.309
21	17	0.042	0.290	0.332	38.214	282.012	320.226	29.299	211.146	240.445	12.2	3.2	332.420	243.617
21	18	0.041	0.303	0.344	37.355	294.044	331.399	28.640	220.155	248.795	12.2	3.2	343.593	251.967
22	16	0.046	0.308	0.354	41.669	299.505	341.174	31.948	224.243	256.191	12.9	3.4	354.055	259.545
22	17	0.045	0.322	0.367	40.813	312.492	353.305	31.292	233.967	265.258	12.9	3.4	366.186	268.612
22	18	0.044	0.335	0.379	39.945	325.547	365.492	30.626	243.741	274.367	12.9	3.4	378.374	277.721
23	16	0.048	0.340	0.389	44.265	330.533	374.798	33.938	247.474	281.413	13.6	3.5	388.368	284.949
23	17	0.048	0.355	0.402	43.400	344.591	387.991	33.275	258.000	291.275	13.6	3.5	401.561	294.811
23	18	0.047	0.369	0.416	42.523	358.718	401.241	32.602	268.577	301.179	13.6	3.5	414.810	304.715
23	19	0.046	0.384	0.430	41.635	372.906	414.541	31.922	279.199	311.121	13.6	3.5	428.110	314.657

Table 2 continued

$d_{1,3}$	h	Volume (m^3)			Mass wet (kg)			Mass dry (kg)			Foliage mass (kg)		Total mass (kg)	
(cm)	(m)	unmerch.	merch.	total	unmerch.	merch.	total	unmerch.	merch.	total	wet	dry	wet	dry
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
24	16	0.051	0.374	0.425	46.851	363.126	409.978	35.921	271.877	307.798	14.3	3.7	424.235	311.490
24	17	0.050	0.390	0.440	45.976	378.303	424.280	35.250	283.241	318.491	14.3	3.7	438.537	322.183
24	18	0.049	0.405	0.455	45.090	393.549	438.639	34.570	294.655	329.225	14.3	3.7	452.896	332.917
24	19	0.048	0.421	0.469	44.192	408.855	453.048	33.882	306.115	339.998	14.3	3.7	467.305	343.690
25	17	0.053	0.426	0.479	48.543	413.622	462.165	37.218	309.684	346.902	14.9	3.9	477.110	350.776
25	18	0.052	0.443	0.495	47.646	430.034	477.681	36.531	321.972	358.503	14.9	3.9	492.625	362.377
25	19	0.051	0.460	0.511	46.739	446.507	493.246	35.835	334.305	370.140	14.9	3.9	508.191	374.014
25	20	0.050	0.477	0.527	45.822	463.035	508.857	35.132	346.680	381.812	14.9	3.9	523.802	385.686
26	18	0.055	0.482	0.537	50.194	468.168	518.362	38.484	350.523	389.007	15.6	4.1	533.995	393.063
26	19	0.054	0.500	0.554	49.277	485.855	535.132	37.781	363.766	401.546	15.6	4.1	550.764	405.602
26	20	0.053	0.519	0.572	48.349	503.597	551.946	37.070	377.049	414.119	15.6	4.1	567.579	418.175
26	21	0.052	0.537	0.589	47.414	521.388	568.801	36.352	390.370	426.722	15.6	4.1	584.434	430.778
27	18	0.058	0.523	0.581	52.734	507.946	560.680	40.431	380.306	420.737	16.3	4.2	577.001	424.975
27	19	0.057	0.543	0.599	51.805	526.895	578.700	39.719	394.493	434.212	16.3	4.2	595.021	438.450
27	20	0.056	0.562	0.618	50.867	545.898	596.765	39.000	408.721	447.721	16.3	4.2	613.086	451.959
27	21	0.055	0.582	0.637	49.921	564.950	614.871	38.275	422.986	461.260	16.3	4.2	631.192	465.498
28	19	0.060	0.587	0.646	54.326	569.622	623.948	41.652	426.483	468.135	17.0	4.4	640.956	472.555
28	20	0.058	0.608	0.666	53.377	589.934	643.311	40.925	441.691	482.616	17.0	4.4	660.320	487.036
28	21	0.057	0.629	0.686	52.420	610.296	662.715	40.190	456.936	497.126	17.0	4.4	679.724	501.546
28	22	0.056	0.650	0.706	51.454	630.702	682.156	39.450	472.215	511.665	17.0	4.4	699.165	516.085
29	19	0.062	0.632	0.695	56.840	614.032	670.872	43.579	459.734	503.313	17.7	4.6	688.569	507.915
29	20	0.061	0.655	0.716	55.879	635.701	691.581	42.843	475.958	518.801	17.7	4.6	709.277	523.403
29	21	0.060	0.677	0.737	54.910	657.420	712.330	42.100	492.219	534.318	17.7	4.6	730.026	538.920
29	22	0.059	0.699	0.759	53.933	679.183	733.116	41.351	508.513	549.864	17.7	4.6	750.813	554.466
30	19	0.065	0.680	0.745	59.347	660.123	719.470	45.502	494.243	539.744	18.4	4.8	737.855	544.528
30	20	0.064	0.704	0.768	58.375	683.197	741.571	44.756	511.518	556.274	18.4	4.8	759.955	561.058
30	21	0.063	0.727	0.790	57.393	706.319	763.713	44.004	528.830	572.834	18.4	4.8	782.097	577.618
30	22	0.062	0.751	0.813	56.404	729.487	785.892	43.245	546.176	589.422	18.4	4.8	804.276	594.206
31	20	0.067	0.754	0.821	60.863	732.417	793.280	46.664	548.370	595.034	19.1	5.0	812.352	600.000
31	21	0.066	0.780	0.845	59.870	756.991	816.861	45.902	566.769	612.671	19.1	5.0	835.933	617.637
31	22	0.064	0.805	0.869	58.868	781.611	840.479	45.135	585.202	630.337	19.1	5.0	859.551	635.303
31	23	0.063	0.830	0.894	57.860	806.272	864.131	44.361	603.666	648.027	19.1	5.0	883.204	652.993

Table 2 continued

$d_{1,3}$	h	Volume (m^3)			Mass wet (kg)			Mass dry (kg)			Foliage mass (kg)		Total mass (kg)	
(cm)	(m)	unmerch.	merch.	total	unmerch.	merch.	total	unmerch.	merch.	total	wet	dry	wet	dry
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
32	20	0.069	0.807	0.876	63.346	783.359	846.704	48.567	586.511	635.078	19.8	5.1	866.464	640.200
32	21	0.068	0.834	0.902	62.340	809.433	871.772	47.796	606.033	653.829	19.8	5.1	891.532	658.951
32	22	0.067	0.861	0.928	61.325	835.552	896.877	47.018	625.588	672.607	19.8	5.1	916.637	677.729
32	23	0.066	0.887	0.953	60.304	861.712	922.016	46.236	645.175	691.410	19.8	5.1	941.776	696.532
33	21	0.071	0.889	0.960	64.803	863.641	928.445	49.685	646.619	696.304	20.4	5.3	948.892	701.608
33	22	0.070	0.918	0.988	63.776	891.308	955.084	48.897	667.333	716.231	20.4	5.3	975.532	721.535
33	23	0.069	0.946	1.015	62.742	919.015	981.757	48.104	688.078	736.182	20.4	5.3	1002.204	741.486
34	21	0.074	0.947	1.021	67.262	919.614	986.876	51.570	688.527	740.097	21.1	5.5	1008.012	745.583
34	22	0.073	0.977	1.050	66.221	948.875	1015.096	50.772	710.435	761.207	21.1	5.5	1036.232	766.693
34	23	0.071	1.007	1.079	65.173	978.177	1043.351	49.968	732.374	782.342	21.1	5.5	1064.486	787.828
34	24	0.070	1.038	1.108	64.119	1007.517	1071.635	49.160	754.340	803.501	21.1	5.5	1092.771	808.987
35	21	0.076	1.007	1.083	69.715	977.350	1047.065	53.451	731.755	785.205	21.8	5.7	1068.888	790.873
35	22	0.075	1.038	1.114	68.660	1008.254	1076.914	52.642	754.892	807.534	21.8	5.7	1098.737	813.202
35	23	0.074	1.070	1.144	67.598	1039.198	1106.796	51.828	778.061	829.888	21.8	5.7	1128.620	835.556
35	24	0.073	1.102	1.175	66.530	1070.179	1136.709	51.009	801.257	852.266	21.8	5.7	1158.533	857.934
36	21	0.079	1.068	1.147	72.163	1036.847	1109.010	55.328	776.300	831.628	22.5	5.9	1131.521	837.478
36	22	0.078	1.101	1.179	71.094	1069.440	1140.534	54.508	800.703	855.211	22.5	5.9	1163.045	861.061
36	23	0.077	1.135	1.212	70.018	1102.074	1172.092	53.683	825.137	878.820	22.5	5.9	1194.603	884.670
36	24	0.076	1.169	1.244	68.935	1134.746	1203.681	52.853	849.598	902.451	22.5	5.9	1226.192	908.301
37	21	0.082	1.131	1.213	74.607	1098.102	1172.709	57.201	822.163	879.364	23.2	6.0	1195.908	885.396
37	22	0.081	1.166	1.247	73.523	1132.433	1205.956	56.370	847.867	904.237	23.2	6.0	1229.155	910.269
37	23	0.079	1.202	1.281	72.432	1166.804	1239.236	55.534	873.601	929.135	23.2	6.0	1262.436	935.167
37	24	0.078	1.237	1.315	71.335	1201.214	1272.548	54.692	899.364	954.056	23.2	6.0	1295.747	960.088
38	22	0.083	1.233	1.316	75.947	1197.230	1273.178	58.229	896.382	954.610	23.9	6.2	1297.065	960.824
38	23	0.082	1.270	1.352	74.841	1233.387	1308.228	57.381	923.453	980.834	23.9	6.2	1332.115	987.048
38	24	0.081	1.307	1.388	73.728	1269.582	1343.310	56.528	950.552	1007.080	23.9	6.2	1367.197	1013.294
39	22	0.086	1.302	1.387	78.367	1263.832	1342.198	60.084	946.247	1006.331	24.6	6.4	1366.773	1012.727
39	23	0.085	1.341	1.425	77.245	1301.821	1379.066	59.224	974.690	1033.914	24.6	6.4	1403.641	1040.310
39	24	0.083	1.380	1.463	76.117	1339.848	1415.965	58.359	1003.161	1061.521	24.6	6.4	1440.540	1067.917
40	23	0.087	1.413	1.500	79.645	1372.105	1451.749	61.064	1027.312	1088.376	25.3	6.6	1477.012	1094.928
40	24	0.086	1.454	1.540	78.501	1412.012	1490.513	60.187	1057.191	1117.378	25.3	6.6	1515.775	1123.930
40	25	0.085	1.495	1.580	77.351	1451.954	1529.304	59.305	1087.096	1146.401	25.3	6.6	1554.567	1152.953

Table 3. Above-ground volume and dendromass data for black locust stands

Site class	Age	Height	Diameter	Number of stems	Total stand														
					Total	Unmerch.	Merch.	Bark	Foliage	Unmerch.	Merch.	Total	Foliage	Total	Unmerch.	Merch.	Total	Foliage	Total biomass
	years	m	cm		m^3					absoute dry mass (t)					green mass (t)				
I	5	7.2	5.2	4045	45	19.2	25.8	7.2	6.5	28.6	46.5	75.1	3.2	78.3	37.3	62.1	99.4	12.9	112.3
	10	13	9.8	2458	134	39.3	94.7	26.5	16.0	24.6	61.8	86.4	2.9	89.3	32.1	82.6	114.7	11.3	126.0
	15	17.4	14.5	1173	178	34.5	143.5	40.2	13.4	22.6	97.6	120.2	2.5	122.7	29.5	130.3	159.8	9.5	169.3
	20	20.6	18.6	785	226	30.7	195.3	50.8	12.8	19.8	130.6	150.4	2.2	152.6	25.8	174.5	200.3	8.5	208.8
	25	22.9	22.0	606	267	30.2	236.8	61.6	12.8	18.1	147.3	165.4	2.0	167.4	23.6	196.7	220.3	7.8	228.1
	30	24.4	24.9	505	304	28.9	275.1	66.0	13.2	17.7	175.1	192.8	2.0	194.8	23.1	233.8	256.9	7.5	264.4
	35	25.5	27.4	441	333	28.3	304.7	73.1	13.6	16.7	186.8	203.5	1.9	205.4	21.8	249.6	271.4	7.2	278.6
	40	26.3	29.7	398	362	26.8	335.2	80.4	14.2	16.8	218.6	235.4	1.9	237.3	21.9	292.0	313.9	7.3	321.2
II	5	6.4	4.7	4595	39	16.7	22.3	6.2	7.4	32.8	46.1	78.9	3.7	82.6	42.8	61.3	104.1	14.7	118.8
	10	11.6	8.8	2793	113	36.2	76.8	21.5	15.4	23.1	51.0	74.1	2.8	76.9	30.1	68.1	98.2	10.9	109.1
	15	15.5	13.0	1333	149	31.3	117.7	33.0	12.7	19.6	76.6	96.2	2.3	98.5	25.6	102.3	127.9	8.9	136.8
	20	18.4	16.6	893	188	32.7	155.3	40.4	11.9	21.2	104.5	125.7	2.2	127.9	27.6	139.6	167.2	8.4	175.6
	25	20.5	19.7	688	222	27.3	194.7	50.6	11.2	18.1	134.2	152.3	2.1	154.4	23.6	179.2	202.8	7.9	210.7
	30	21.8	22.3	574	252	28.5	223.5	53.6	10.5	17.1	139.5	156.6	1.9	158.5	22.3	186.3	208.6	7.4	216.0
	35	22.8	24.5	502	278	26.4	251.6	60.4	10.6	17.6	174.0	191.6	1.9	193.6	22.9	232.5	255.4	7.5	262.9
	40	23.5	26.6	452	300	25.5	274.5	65.9	10.4	17.1	191.5	208.6	2.0	210.5	22.3	255.8	278.1	7.4	285.5
III	5	5.6	4.2	5295	32	13.7	18.3	5.1	8.5	37.8	53.1	90.9	4.2	95.1	49.3	70.6	119.9	16.9	136.8
	10	10.2	7.7	3225	94	34.3	59.7	16.7	14.5	22.1	40.1	62.2	2.6	64.8	28.9	53.5	82.4	10.3	92.7
	15	13.7	11.5	1539	122	29.0	93.0	26.0	13.1	20.5	68.1	88.6	2.5	91.1	26.7	91.0	117.7	9.2	126.9
	20	16.2	14.7	1031	153	29.7	123.3	32.1	11.8	19.8	85.7	105.5	2.2	107.7	25.9	114.5	140.4	8.4	148.8
	25	18	17.4	795	181	31.5	149.5	38.9	10.6	18.9	93.1	112.0	2.0	114.0	24.6	124.3	148.9	7.5	156.4
	30	19.2	19.7	663	204	25.1	178.9	42.9	10.8	17.5	129.3	146.8	2.0	148.8	22.8	172.7	195.5	7.6	203.1
	35	20.1	21.6	579	225	25.4	199.6	47.9	10.6	17.3	140.7	158.0	1.9	159.9	22.5	187.9	210.4	7.5	217.9
	40	20.7	23.4	522	243	25.8	217.2	52.1	10.0	16.6	145.2	161.8	1.8	163.6	21.6	193.9	215.5	7.1	222.6

Table 3 continued

Site class	Age	Height	Diameter	Number of stems	Total stand														
					Total	Unmerch.	Merch.	Bark	Foliage	Unmerch.	Merch.	Total	Foliage	Total	Unmerch.	Merch.	Total	Foliage	Total biomass
	years	m	cm		m^3					absoute dry mass (t)					green mass (t)				
IV	5	4.8	3.6	6 254	26	11.1	14.9	4.2	10.0	44.7	62.7	107.4	5.0	112.4	58.2	83.4	141.6	20.0	161.6
	10	8.8	6.7	3801	75	29.4	45.6	12.8	13.7	26.9	43.7	70.6	3.0	73.6	35.1	58.3	93.4	12.2	105.6
	15	11.8	9.9	1814	98	28.7	69.3	19.4	11.8	18.2	45.6	63.8	2.2	66.0	23.7	60.9	84.6	8.3	92.9
	20	14	12.7	1215	121	25.4	95.6	24.9	11.5	17.9	69.8	87.7	2.1	89.8	23.3	93.2	116.5	8.1	124.6
	25	15.6	15.1	937	144	27.9	116.1	30.2	10.7	18.0	77.9	95.9	2.0	97.9	23.5	104.1	127.6	7.6	135.2
	30	16.7	17	781	162	28.2	133.8	32.1	10.4	18.5	91.4	109.9	2.0	111.9	24.2	122.1	146.3	7.3	153.6
	35	17.4	18.8	683	177	24.1	152.9	36.7	10.4	17.2	113.7	130.9	1.9	132.8	22.4	151.8	174.2	7.4	181.6
	40	17.9	20.3	615	192	23.6	168.4	40.4	10.0	16.2	120.0	136.2	1.8	138.0	21.1	160.2	181.3	7.1	188.4
V	5	4.1	3	7568	21	9.0	12.0	3.4	12.1	54.0	75.9	129.9	6.1	136.0	70.5	101.0	171.5	24.2	195.7
	10	7.4	5.7	4604	59	25.0	34.0	9.5	12.0	32.9	46.2	79.1	3.7	82.8	42.9	61.4	104.3	14.7	119.0
	15	10	8.4	2198	76	29.8	46.2	12.9	9.9	15.1	27.3	42.4	1.8	44.2	19.7	36.5	56.2	7.0	63.2
	20	11.8	10.7	1472	94	23.2	70.8	18.4	11.0	16.3	51.5	67.8	2.1	69.9	21.2	68.7	89.9	7.8	97.7
	25	13.2	12.7	1135	110	23.1	86.9	22.6	10.8	16.7	65.2	81.9	1.9	83.8	21.8	87.1	108.9	7.6	116.5
	30	14.1	14.4	946	124	24.9	99.1	23.8	9.9	16.2	67.0	83.2	1.9	85.0	21.2	89.5	110.7	7.0	117.7
	35	14.7	15.9	827	136	23.9	112.1	26.9	10.2	17.3	84.2	101.5	1.8	103.4	22.6	112.4	135.0	7.2	142.2
	40	15.1	17.2	745	146	25.4	120.6	28.9	9.9	17.7	87.2	104.9	1.8	106.8	23.1	116.5	139.6	7.0	146.6
VI	5	3.3	2.5	9538	15	6.4	8.6	2.4	15.3	68.1	95.7	163.8	7.6	171.4	88.8	127.2	216.0	30.5	246.5
	10	6	4.6	5796	45	19.2	25.8	7.2	9.3	41.4	58.2	99.6	4.6	104.2	54.0	77.3	131.3	18.5	149.8
	15	8.1	6.9	2767	56	23.9	32.1	9.0	10.0	19.8	27.8	47.6	2.2	49.8	25.8	36.9	62.7	8.9	71.6
	20	9.7	8.8	1 853	69	22.1	46.9	12.2	10.2	15.3	33.8	49.1	1.9	51.0	20.0	45.2	65.2	7.2	72.4
	25	10.7	10.4	1429	80	23.4	56.6	14.7	9.3	14.3	35.9	50.2	1.9	51.9	18.7	48.0	66.7	6.6	73.3
	30	11.5	11.8	1191	90	21.4	68.6	16.5	10.1	15.8	52.7	68.5	1.9	70.4	20.7	70.4	91.1	7.1	98.2
	35	12	13	1041	99	22.7	76.3	18.3	9.9	16.0	56.0	72.0	1.8	73.8	20.8	74.8	95.6	7.0	102.6
	40	12.3	14.1	938	107	23.8	83.2	20.0	9.8	16.4	59.9	76.3	1.8	78.1	21.4	80.1	101.5	6.9	108.4

4 DISCUSSION AND CONCLUSIONS

In many countries and regions there is an increasing need to express the productivity of forests in terms of weight, particularly in plantation forests that are managed for the production of industrial timber. A similar situation arises when trees are planted or natural forests are managed to produce wood energy, since mass rather than volume is a measure to quantify the production of wood for energy.

Biomass data is also important in carbon sequestration and balance studies because biomass tables provide additional data and information that conventional timber volume tables lack.

According to our yield table (Rédei 1984), the total stand volume varies between 80 and 280 m^3/ha in function of yield classes at the age of 30 years, which is the average rotation age for black locust stands in Hungary.

Yield Class I–II black locust stands are treated with a rotation of 35–40 years, and a mean annual increment of total production of 12–14 m^3/ha/yr. can be expected. Yield Class III–IV stands have a rotation of 30 years with an MAI of 8–9 m^3/ha/yr. Finally, the poorest stands (Yield Class V–VI) have a rotation of 20–25 years and an MAI of 4–6 m^3/ha/yr. The growing stock, increment, and health of first generation coppice stands are similar to those in high forests.

A large proportion of high quality saw logs is the aim of final felling in yield class I and II stands. In yield classes III and IV stands, the production of some saw logs with a high proportion of poles and props is the goal. Yield class V–VI stands are expected mainly to yield poles, props, other industrial wood products of smaller dimensions, and fuelwood. Primarily these forests serve a protective function.

Single black locust tree raw green volume of foliage (m^3) ranging from 0.0006 m^3 to 0.0358 m^3 related to the breast height diameter (ranging from 4 to 40 cm) can be seen in *Table 1*. Mass of foliage (raw green) values range from 0.0005 t to 0.0252 t, and the absolute dry mass of foliage values range from 0.0001 t to 0.0065 t.

Weight and volume tables regarding single black locust trees and black locust stands presented in this study are unique and, therefore, fill a knowledge gap that currently exists in the international literature.

Table 4. Volume and dendromass data for black locust stands at the age of 30

Site class	Height	Diameter	Number of stems	Total stand				
					Absolute dry mass		Green mass	
	(m)	(cm)		m^3	(t)	%	(t)	%
I	24.4	24.9	505	304	194.8	100	264.4	100
II	21.8	22.3	574	252	158.5	81.37	216.0	81.69
III	19.2	19.7	663	204	148.8	76.39	203.1	76.82
IV	16.7	17	781	162	111.9	57.44	153.6	58.09
V	14.1	14.4	946	124	85.0	43.63	117.7	44.52
VI	11.5	11.8	1191	90	70.4	36.14	98.2	37.14

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