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Simplified volume equations for grey poplar (*Populus* × *canescens* Smith.) standing trees

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SUMMARY

Grey poplar (Populus× canescens Smith.) is a natural hybrid of white poplar (Populus alba L.) and Eurasian aspen (Populus tremula L.). It can be found throughout Europe, where both parents are present. The above mentioned species of poplars (under the term of 'domestic poplars') cover approximately 5% of the forests of Hungary. Of these species, grey poplar holds significance in forestry, and its role in afforestation shows a growing tendency. For this reason, improving the growing technology of grey poplar is a timely topic. In this paper we introduce algorithms which help estimate grey poplar tree volumes without having to use volume tables. Based on the performed evaluations, both equations can be used for single tree volume estimation with an error of less than 5%.

Keywords: *grey poplar; volume equations*

INTRODUCTION

Grey poplar (*Populus* × *canescens* Smith.) is one of the most valuable tree species amongst the endemic poplar species in Hungary. It is a natural hybrid of white poplar (*Populus alba* L.) and Eurasian aspen (*Populus tremula* L.) (Csapody et al., 1966). It covers about 96 000 hectares, which is about 5% of the forested area of Hungary, with the other endemic poplar species included (NLC, 2022). Grey poplar is characterized by fast growth, good quality multipurpose wood, good tolerance to pests, diseases, and relatively low demand of site quality (Tóth, 1978). It is also relatively drought tolerant. Based on this, and on its role in mitigating the negative influence of climate change on forest production, it has been becoming more relevant in the afforestation in Hungary (Komán et al., 2023), specifically on sandy, partially marginal sites (Rédei and Keserű, 2022). There are several reasons to accelerate research and innovation regarding grey (and white) poplars. Decline of ecological conditions, such as reduced amount of precipitation in the vegetation period, inappropriate water management and deeper groundwater table leads to the need of new cultivars (clones), which are able to adapt to the new ecological conditions (Keserű and Rédei, 2012). As for the growers, they also play key role in improving the quality as well as increasing the productivity of poplar stands (Rédei, 2000). Grey poplar stands in Hungary belong to the class of 'cultural forests' of the ecological classification of forests, and their growing technology is characterized by plantation forestry (fast growth, shorter harvesting cycle, wider initial and final planting spacing, higher expectations on profitability, etc.). Due to this, to meet the criteria of successful implementation, the inventory of the produced and planned timber production (volume) needs to be accounted with an easy, fast and trusted (verified) manner, which method can be adapted widely. Although traditional growth models acquired by data on the stand level are well established methods, individual tree growth models and stem number frequencies have become more relevant in forest inventories in the past few decades (Rédei and Keserű, 2012). The ultimate goal of measuring trees is to determine the amount of wood contained in their stems and the sizes of the logs they form. (West, 2009). The investigation of forest yields can be done based on individual trees, on one specific forest stand, or on a larger block of forest which consists of several forest stands. (Veperdi, 2011). The problem with forest yield research is that biological processes shall be assessed quantitatively. As opposed to agricultural crops, which are harvested annually and can be easily handled by man, forest trees are troublesome by the means of their size, hence it is difficult to measure their volume and weight (Assmann, 1970). In case of Spain, the need of simplified volume equations for poplar plantations was formulated by farmers who also own plantations and often lack the knowledge of forestry. Blanco and Blanco (2021) developed a simple equation which only requires the diameter of individual trees to estimate the tree volume, which underlines the importance of such simplified equations in practice.

This study aims to introduce two algorithms which only require the average diameter at breast height (dbh) and height (h) of the trees of a given stand, without the need of yield tables (volume) or other supplementary data.

MATERIALS AND METHODS

Temporary sample plots (500–1000 m^2) have been established in 38 grey poplar stands in the Danube-Tisza Interfluve region, in the central part of Hungary, near the settlements of Kunpeszér, Hetényegyháza, Kecskemét, Kunadacs, Tompa and Kelebia (*Figure 1*). The age of stands varied between 14 and 33 years. The main stand structures had been recorded and yield statistics were calculated.

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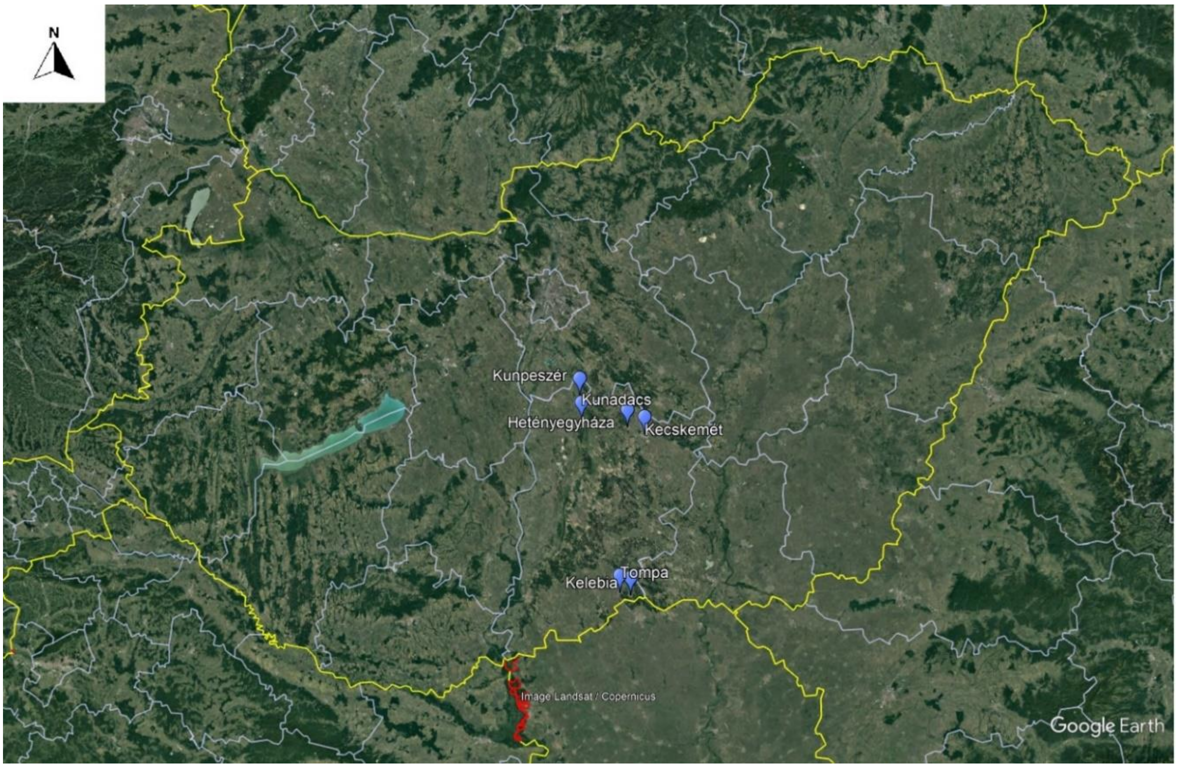
Figure 1. **Location of the sample plots**



Volumes were calculated on the basis of stem-by-stem estimates. First, semi-logarithmic diameter-height regressions were prepared. Subsequently, these regressions were used for estimating the height of each tree. Finally, volumes were estimated using the volume functions developed by Sopp and Kolozs (2013).

$$v = 10^{-8}\, dbh^2 h^1\, [h/(h-1.3)]^2\, [-0.4236\, dbh\, h + 12.43\, dbh + 3298], \quad (1)$$

v = stem volume (m^3)
dbh = diameter at breast height (cm)
h = height (m)

The main stand structures of the investigated grey poplar stands and their yield parameters can be seen in *Table 1*.

The following equations were tested for estimating tree volume (v= average volume of the trees, m^3):

$$v = q\, dbh^2\, (h+3), \text{ where } q = 0.35 \quad (2)$$

$$v = dbh^2\, [(h+3)/3] \text{ (Király, 1985; Sopp and Kolozs, 2013)}, \quad (3)$$

v = V/N, which stands for the control (the parameters are presented in *Table 1*) (4)

The reason for no detailed mathematical-statistical analyses is the fact that we did not use primary, but secondary data to compare the tree yields (volume). The investigated formulas for estimating volumes are based on algorithms, and they do not follow normal distribution as compared to primary data (dbh, height), which characterizes forest dendrometry. We used the method to decide the goodness of the equations by comparing it to the control, and expressing the difference in percentage, as it is used in forest assessments. If the difference is less than 10% the equation is qualified good to predict the yield of the trees.

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Table 1. **Main stand structures and yield parameters**

Subcompartments	Age (yr)	H (m)	DBH (cm)	V (m^3 ha^{-1})	BA (m^2 ha^{-1})	N (stem ha^{-1})	v (m^3)
Kunpeszér 26A	14	11.9	8.2	54.26	8.437	1600	0.034
Kelebia 27É	16	16	14.3	125.5	14.414	900	0.139
Kelebia 79C	17	14.7	12	78.66	9.934	880	0.089
Kunadacs 42B	17	15.9	14.6	206.48	23.877	1420	0.145
Hetényegyháza 10F	17	22.3	26.1	242.65	21.315	400	0.607
Hetényegyháza 10E	17	14.2	18	124.82	15.255	600	0.208
Kunpeszér 18B	18	11.9	11	106.48	16.109	1690	0.063
Kecskemét 8A	18	12.9	12.1	136.86	19.238	1660	0.082
Tompa 53E	18	13.9	12.5	95.42	12.69	1040	0.092
Kelebia 107C	18	15.6	13.6	102.58	12.137	840	0.122
Kecskemét 7D	19	15.3	16.2	136.66	16.13	780	0.175
Kunadacs 41G	20	13.6	11.4	74.94	10.172	1000	0.075
Kunpeszér 11C	21	12.5	11.7	119.12	17.391	1620	0.074
Kunpeszér 11E	22	18.5	18.5	176.49	18.013	670	0.263
Kunpeszér 19H	22	21.5	22.4	277.67	25.17	640	0.434
Tompa 58I	22	17.6	17	161.46	17.241	760	0.212
Kunpeszér 8C	23	15.5	15.2	146.66	17.678	970	0.151
Kunpeszér 25B	24	19.3	22.7	149.41	14.6	360	0.415
Kelebia 61B	25	20.4	21.6	370.5	34.985	960	0.386
Tompa 52I	26	17.4	18.8	180.46	20.458	740	0.244
Tompa 16A	26	22.2	23.4	272.68	24.162	560	0.487
Tompa 52H1	26	14.7	16.4	144.68	17.769	840	0.172
Tompa 52H2	26	17.5	20.7	203.1	21.448	640	0.317
Kelebia 53C	26	20.3	22.6	222.18	20.87	520	0.427
Kunpeszér 10D	26	17	19	177.24	19.509	690	0.257
Kunadacs 41H	27	21.8	25.6	247.33	22.191	430	0.575
Tompa 51F	27	21.4	21.8	212.78	20.119	540	0.394
Tompa 12C	27	16.6	18.3	184.84	20.44	780	0.237
Tompa 50J	28	18.2	19.7	190.18	19.565	640	0.297
Hetényegyháza 12B	28	20.3	21.3	242.38	22.908	640	0.379
Hetényegyháza 15B	28	25.2	29	293.16	23.704	360	0.814
Tompa 56A	29	21.5	21.8	225.22	22.314	600	0.375
Kelebia 6D	30	26.1	28.2	396.04	31.209	500	0.792
Tompa 1E	30	19.6	20	254.96	27.133	860	0.296
Tompa 7A	30	21.2	27.1	219.8	21.914	380	0.578
Hetényegyháza 5D	30	21.8	29.3	288.4	25.634	380	0.759
Tompa 50F	31	16.3	14.8	96.94	11.361	660	0.147
Kunadacs 42L	33	13.7	13.6	78.82	10.475	720	0.109

H = mean height of the stand; DBH = mean diameter (at breast height) of the stand; V = volume per hectare; BA = basal area per hectare; N = stem number per hectare; v = mean tree volume of the stand.

RESULTS AND DISCUSSION

The volume-equations to predict the tree volume are mainly used to create yield tables (volume) by modelling the relationship between the diameter at breast height (dbh) and the height (h) of the tree. In Hungary, equation (2) is used in practice, which was formulated from data of yield tables (volume) based on the stand characteristics (Király, 1985; Sopp and Kolozs, 2013). Volume equation (3) is similar to equation (2), but it doesn't require the factor q. The local applicability of volume equations can be verified by defining the volume of the tree in sections of randomly selected sample trees, or by xylometry or by measuring its mass.

Based on *Table 2* it can be stated that the dataset derived from the tested equations only differ with an average of 5%, which is acceptable, as it is way below the allowed error value of 10% (Veperdi, 2011). The method to estimate single tree volume by equations – as introduced above – is only one of the factors to define the total volume of a stand per hectare. To do so,

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the number of trees per hectare (N) also has to be specified (V=vN) which can be done in several ways. For example, counting the number of trees per unite area, or counting the number of trees at the time of measuring the total basal area. This data can also be acquired by the approximate diameter of the crown (CD), which in case of rectangular tree spacing N = $10000/CD^{2,}$ and for triangle spacing N = $11550/CD^2$.

Table 2. **Average tree volume of the studied grey poplar stands calculated with the volume equations and compared to the control (%)**

Subcompartments	**Control (v = V/N) (m^3)**	**Equation 2 (m^3)**	**Difference from the control (%)**	**Equation 3 (m^3)**	**Difference from the control (%)**
Kunpeszér 26A	0.034	0.035	+3%	0.033	-2%
Kelebia 27É	0.139	0.136	-2%	0.130	-7%
Kelebia 79C	0.089	0.089	0%	0.085	-5%
Kunadacs 42B	0.145	0.141	-3%	0.134	-8%
Hetényegyháza 10F	0.607	0.603	-1%	0.574	-5%
Hetényegyháza 10E	0.208	0.195	-6%	0.186	-11%
Kunpeszér 18B	0.063	0.063	0%	0.060	-5%
Kecskemét 8A	0.082	0.081	-1%	0.078	-6%
Tompa 53E	0.092	0.092	+1%	0.088	-4%
Kelebia 107C	0.122	0.120	-1%	0.115	-6%
Kecskemét 7D	0.175	0.168	-4%	0.160	-9%
Kunadacs 41G	0.075	0.076	+1%	0.072	-4%
Kunpeszér 11C	0.074	0.074	+1%	0.071	-4%
Kunpeszér 11E	0.263	0.258	-2%	0.245	-7%
Kunpeszér 19H	0.434	0.430	-1%	0.410	-6%
Tompa 58I	0.212	0.208	-2%	0.198	-7%
Kunpeszér 8C	0.151	0.150	-1%	0.142	-6%
Kunpeszér 25B	0.415	0.402	-3%	0.383	-8%
Kelebia 61B	0.386	0.382	-1%	0.364	-6%
Tompa 52I	0.244	0.252	+3%	0.240	-1%
Tompa 16A	0.487	0.483	-1%	0.460	-6%
Tompa 52H1	0.172	0.167	-3%	0.159	-8%
Tompa 52H2	0.317	0.307	-3%	0.293	-8%
Kelebia 53C	0.427	0.417	-3%	0.397	-7%
Kunpeszér 10D	0.257	0.253	-2%	0.241	-6%
Kunadacs 41H	0.575	0.569	-1%	0.542	-6%
Tompa 51F	0.394	0.406	+3%	0.387	-2%
Tompa 12C	0.237	0.230	-3%	0.219	-8%
Tompa 50J	0.297	0.288	-3%	0.274	-8%
Hetényegyháza 12B	0.379	0.370	-2%	0.352	-7%
Hetényegyháza 15B	0.814	0.830	+2%	0.791	-3%
Tompa 56A	0.375	0.408	+9%	0.388	+3%
Kelebia 6D	0.792	0.810	+2%	0.771	-3%
Tompa 1E	0.296	0.316	+7%	0.301	+2%
Tompa 7A	0.578	0.622	+8%	0.592	+2%
Hetényegyháza 5D	0.759	0.745	-2%	0.710	-6%
Tompa 50F	0.147	0.148	+1%	0.141	-4%
Kunadacs 42L	0.109	0.108	-1%	0.103	-6%
Average difference from the control			**0%**		**-5%**

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CONCLUSIONS

The volume equations discussed in this study are mainly beneficial for larger forest stands, which consist of numerous forest subcompartments. Amongst the two equations v = dbh^2 [(h+3)/3] is simpler, because it does not require the factor q. Further investigations are needed regarding the economic viability of the above discussed methods. It is suggested to do similar analyses for other relevant stand-forming tree species. All of this could also contribute to the spread of such innovative and rapid tree volume estimation methods, in practice.

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