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Determination of the biomass of *Pinus mugo* stands

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Abstract: The dwarf pine stands on unoriginal sites in mountainous areas of the Czech Republic are a current topic of scientific discussion. One of these sites is on the summits of the Hrubý Jeseník Mts. Various proposals for dwarf pine removal have been hindered by the absence of charts or tables that could be used to calculate how much biomass would need to be removed. Therefore, we created a methodology for dwarf pine biomass determination and applied it to five research transects of different ages. Based on the biomass estimates, we created trend curves illustrating the increase in biomass (dependent on age) as well as equations that could be used to roughly estimate the biomass of any dwarf pine stand, regardless of age or canopy level, for sites above the timberline in Hrubý Jeseník Mts. The equations for biomass calculations could also be applied to other mountain ranges where artificially planted dwarf pines of the same seed origin or the same morphological appearance as those existing in the Hrubý Jeseník Mts. are found.

Additional key words: dwarf pine, aboveground biomass, issue of indigeneity (originality problem), removal

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Introduction

Pinus mugo Turra /syn. *P. mugo* ssp. *mughus* (Scop.) Dom./ is a variable and taxonomically complicated species. Complex of this pine has many unknown traits, including the origin of the taxa, the classification and the natural range of *Pinus mugo*. The issues of its origin and the taxonomic classification of individual shrubs and populations have been addressed by many methods examining various properties of specimens or entire populations. Older methods include studying morphological and anatomical features, such as biometric analyses, but advances in technology favor newer polyprenol analyses, isoenzyme genotype analyses and allozyme studies of genetic variability.

The presence of non-indigenous or probable non-indigenous stands in the Jeseníky, Orlické hory and Krkonoše mountains has become a topic of much debate in the Czech Republic. The dwarf pine is indigenous to the peat bogs of the supramontane belt of the Krkonoše Mts. and is also a natural component of many biotopes within the subalpine belt. However, introduced dwarf pines grown from seeds from Germany or Austria were planted in the ridges at the end of the 19th century (Lokvenc 2003). These non-indigenous stands have recently been carefully and gradually removed.

The non-indigeneity of the dwarf pine in the Hrubý Jeseník Mts. (part of the Jeseníky Mts.) has been discussed because these mountains contain more than 350 ha (Šenfeldr et al. 2012) of planted dwarf pine stands. These stands thrive, as they are typical mountain heliophytes with optimal growth design. The dwarf pine was first planted in the Hrubý Jeseník Mts. in 1877 in the Bruntál domain (because of shift of the timberline and water flow regulation) and the planting continued in 1921 after disastrous landslides in the Šumperk district. The seed for these plantings was purchased in Innsbruck or in Wiener Neustadt. Other, more extensive planting occurred in the 1970s in the area of Petrovy kameny – Velký Máj, including the cirques of Velká kotlina and Malá kotlina. Unfortunately, there are no records about the origin of seed (Holubičková 1980).

Due to the alleged influence of the dwarf pine on the gradual deterioration of the condition of several valuable eco-phenomena of the Hrubý Jeseník summits (e.g., disruption of arcto-alpine communities of tundra character), several proposals for dwarf pine reduction have been created and partially implemented by the Administration of the Protected Landscape Area of Jeseníky Mts.

In response to the dwarf pine reduction proposals (without solution of technical-institutional aspects of the problem), the primary aim of this study, funded by the GS LČR (Grant service of the Forests of the Czech Republic), is to estimate the aboveground biomass of the dwarf pines growing above the timberline in the Hrubý Jeseník Mts. that would have to be addressed before the potential removal of the stands. Because there are no tables that determine the biomass of the dwarf pine stands, the aims of this study were to create a methodology for determining the dwarf pine biomass and trend curves expressing the increase in biomass based on age. These tools were further used to derive equations for biomass estimation in all dwarf pine stands in Hrubý Jeseník Mts., of various age classes and various levels of canopy (meant as various canopy density).

Overview of the literature on dwarf pine growth and the formation of biomass

Authors have generally concentrated more on dwarf pine growth dynamics than on the biomass. There are essentially three categories of research:

1. Studies about the dynamics of dwarf pine stands using analyses of aerial photos.

   These studies compare the current conditions with those shown in historical aerial photos and are analyses of the changes in the cover of dwarf pine stands over time. This topic has been addressed by many Czech and foreign authors using manual visual methods and automated classification methods, e.g., Fišerová (1991), Lokvenc and Vacek (1991), Carmel and Kadmon (1998), Kadmon and Harari-Kremer (1999), Potočka (1999), Souček et al. (2001), Halounová (2004), Müllerová (2005), Wild (2006a), Palombo et al. (2013) and others.

   The dynamics of dwarf pine stands using analyses of aerial photos specifically in the Hrubý Jeseník Mts. have been addressed by Hošek et al. (2005), Wild (2006b), Wild et al. (2007).

2. Studies about the growth dynamics of dwarf pine stands using dendrometric and dendrochronological methods.

   Analyses of the diameter increments of the dwarf pine have been conducted by Kolischuk and Berko (1967), Kolischuk (1969), Heikkinen (1980), Bitterli (1987), Corona (1987a), Simon and Drápela (1987) and Hohl et al. (2002), Kyncl and Wild (2004), Špinlerová and Martinková (2006, 2009), Palombo et al. (2014), among others.

   Jeseníky dwarf pines on sites exposed to pollution were studied partially by Simon and Drápela (1987). Their results showed that the diameter increment had not fluctuated for thirty years. Dendrochronological analyses of selected shrubs in Hrubý Jeseník Mts. were performed by Hošek et al. (2005).

3. Studies about the growth dynamics of dwarf pines based on length increment.

   The length increment of the dwarf pine has not been well monitored. An older study by Popovic (1976) describes the growth of the dwarf pine in the Vršič Mts. and a more recent study by Špinlerová and Martinková (2006) contains a growth analysis of the dwarf pine in the Orlické hory Mts. The length increment of the dwarf pine (specifically the length of the last ten increments of the main branches) in Jeseníky Mts. was studied by Hošek et al. (2005).

The knowledge gained from studies into the dynamics of stands provides a foundation for theories about the speed of biomass formation. Literature summarizing the data about the amounts of dwarf pine biomass (of single specimens or entire stands) is scarce. The authors more often address the biomass of the herbal (moss) growth under the dwarf pine – e.g., Kubíček et al. (1983), Kubíček (2001) – or the total aboveground biomass of the community. Bliss (1962) provided a production of tundra ecosystems within one growing season and the productivity of the natural tundra communities was evaluated by Malinovskij (1984) and Archibold et al. (1995). The volume and weight of the "stems" and branches and the weight of needles within one dwarf pine specimen growing at an altitude of 1900 m in the Vršič Mts. was published by Popovic (1976). The range of the determined volume of dwarf pine stems from eastern Trentino (Northern Italy) presented Corona (1987b).

Methods

The original intention – to determine the biomass of one specimen or the polycormon of one mother plant – was abandoned after the terrain survey. The dwarf pines in the area grow wildly with a complicated vegetative propagation, which makes terrain orientation impossible. Therefore, five representative 100% closed-canopy transects of non-indigenous stands (with areas of 4 m^2) of different ages or dwarf pine heights (stands of the 15th, 8th, 4th and 2nd age class) were selected on sites near the summit of Keprník (K) and in the Větrná louka (V) /Fig. 1, Table 1 /. (One age class in the Czech forestry terminology in this case means age range of 10 years. For example, the stand of the 2nd age class may have 11 to 20 years.) All transects were located in the Protected Landscape Area, transects K also in the National Nature Reserve (NNR) Šerák – Keprník and V in the NNR Praděd.

The dwarf pine is, as mentioned, in all selected transects difficult growing, generating polycormons. Shrubs are densely branched, closed. The main branches (plumules) of the shrubs are loosing terminal character (the apical dominance); reaching almost the same height that does not exceed 3.5 m. The branches are prostrate at the base, but then bent into an arc and grow into an upright form (form is close to cubic paraboloid).

The understory in these stands (transects) is very poor, only with a few species, as *Vaccinium myrtillus*, *Avenella flexuosa*, *Calamagrostis villosa*, *Nardus stricta*, *Trientalis europaea* or *Calluna vulgaris*.

All aboveground dwarf pine biomass was removed from the transects.

The material was transported to the laboratory, where the fresh mass and volume were measured. The masses of the large timber (the above-ground woody mass including bark with a diameter greater than 0.07 m), small timber (the above-ground woody mass including bark with a diameter less than 0.07 m) and needles were determined separately using a hanging scale (digital, 100 g accuracy). The mass of cones was determined using a electronic scales Kern 822 (1000 g accuracy). The volume of the large timber was calculated as the sum of volumes of 25 cm sections using a formula for the calculation of a truncated cone (Packová and Maděra 2004).

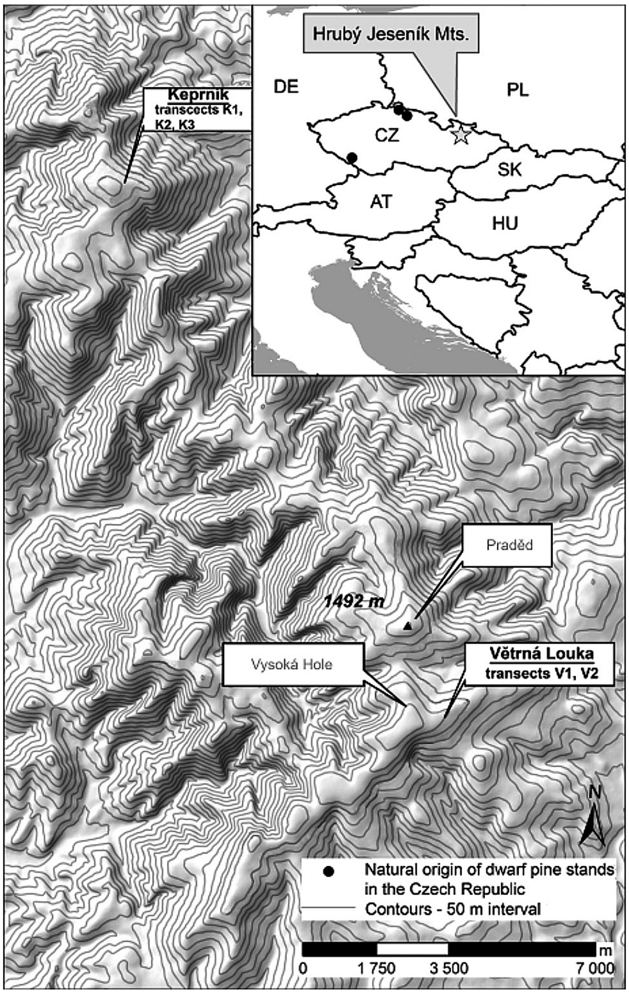

Fig. 1. The overall study area with location of representative transects K1, K2, K3 and V1, V2. All dwarf pine stands in Hrubý Jeseník Mts. are non-indigenous. Natural stands in the Czech Republic are relatively distant, as also natural stands in Poland or in Slovakia

Truncated cone calculation formula:

$$V = \frac{\pi v}{3}(r_1^2 + r_1 r_2 + r_2^2)$$

where r_1 and r_2 are the radii of the bases; v is the height.

The volume of the small timber and needles was calculated from the determined fresh mass and vol-

Table 1. Location of the selected transects

Site	Transect	Age class	Latitude	Longitude
Keprník	K1	15 (150 years)	50°10'13.687"N	17°7'1.709"E
Keprník	K2	15 (150 years)	50°10'13.060"N	17°7'2.387"E
Keprník	K3	8 (80 years)	50°10'15.164"N	17°7'1.963"E
Větrná louka	V1	4 (39 years)	50°3'48.504"N	17°14'31.664"E
Větrná louka	V2	2 (18 years)	50°3'52.163"N	17°14'30.024"E

Fig. 2. Transect K3 – 80-year-old stand (the stand of the 8th age class) in Keprník (Photo: Z. Špinlerová)

ume of ten sample branches and fifty couples of needles in the graduated cylinder.

Next, the material was dried at 105° C in the drying chamber to a constant weight and the dry mass was determined (using the digital hanging scale, for cones using electronic scales). Samples of needles (10 couples from each year) were scanned both before and after drying and their area was determined using the Quick PHOTO MICRO application (developed by Promicra, s.r.o.; Prague; Czech Republic; Europe). The area of the sample needles was averaged for each year and the average was used to calculate the total area of the needles (the needle surface area calculated from the averaged surface area of needles and the total number of needles occurring in the area of 4 m^2).

All of the results were converted to an area of 1 m^2, or 1 ha. The values for the two 150-year-old plots were averaged.

Based on the results from the transects, trend curves expressing the increase in fresh biomass (mass and volume) in relation to age were created; further, the trend curves were used to derive equations for the biomass calculation for dwarf pine stands of different age classes.

The equations were used to express the biomass of all dwarf pine stands with different canopy levels on sites above the timberline of the Hrubý Jeseník Mts.

Results

Figure 2 shows the process of setting out the selected plots.

The results for specific transects are presented in Table 2. The results converted to an area of 1 m^2, are in Table 3. The parameters were determined separately for large timber, small timber, needles and

Table 2. Parameters determined in selected transects

Transect K1 (≈ 150 yr)		Transect K2 (≈ 150 yr)		Transect K3 (≈ 80 yr)		Transect V1 (≈ 40 yr)		Transect V2 (≈ 20 yr)	
Height ≈ 2.5 m		Height ≈ 3.2 m		Height ≈ 1.3 m		Height ≈ 1.3 m		Height ≈ 1.2 m	
Fresh mass/4 m^2		Fresh mass/4 m^2		Fresh mass/4 m^2		Fresh mass/4 m^2		Fresh mass/4 m^2	
Large timber	60 kg	Large timber	93.3 kg	Large timber	10.0 kg	Large timber	2.6 kg	Large timber	1.3 kg
Small timber	33.5 kg	Small timber	5.1 kg	Small timber	50.1 kg	Small timber	42.9 kg	Small timber	39.2 kg
Needles	5.8 kg	Needles	14.5 kg	Needles	12.2 kg	Needles	13.4 kg	Needles	13.5 kg
Cones	0.8 kg	Cones	0.8 kg	Cones	1.0 kg	Cones	0.488 kg	Cones	0.130 kg
Total	100.1 kg	Total	113.7 kg	Total	73.3 kg	Total	59.388 kg	Total	54.13 kg
Dry mass/4 m^2		Dry mass/4 m^2		Dry mass/4 m^2		Dry mass/4 m^2		Dry mass/4 m^2	
Large timber	40.6 kg	Large timber	63.8 kg	Large timber	6.8 kg	Large timber	1.6 kg	Large timber	0.6 kg
Small timber	22.2 kg	Small timber	2.3 kg	Small timber	34.1 kg	Small timber	25.3 kg	Small timber	19.2 kg
Needles	2.8 kg	Needles	6.5 kg	Needles	6.5 kg	Needles	6.4 kg	Needles	6.8 kg
Cones	0.4 kg	Cones	0.420 kg	Cones	0.532 kg	Cones	0.242 kg	Cones	0. 065 kg
Total	66 kg	Total	73.02 kg	Total	47.932 kg	Total	33.542 kg	Total	26.665 kg
Fresh mass volume/4 m^2		Fresh mass volume/4 m^2		Fresh mass volume/4 m^2		Fresh mass volume/4 m^2		Fresh mass volume/4 m^2	
Large timber	0.08 m^3	Large timber	0.12 m^3	Large timber	0.0284 m^3	Large timber	0.0072 m^3	Large timber	0.0024 m^3
Small timber	0.04 m^3	Small timber	0.01 m^3	Small timber	0.1036 m^3	Small timber	0.0776 m^3	Small timber	0.0612 m^3
Needles	0.0444 m^3	Needles	0.0912 m^3	Needles	0.0544 m^3	Needles	0.0704 m^3	Needles	0.0664 m^3
Total	0.1644 m^3	Total	0.2212 m^3	Total	0.1864 m^3	Total	0.1552 m^3	Total	0.1300 m^3
Needle area/4 m^2		Needle area/4 m^2		Needle area/4 m^2		Needle area/4 m^2		Needle area/4 m^2	
Fresh	8. 36 m^2	Fresh	20.52 m^2	Fresh	21.64 m^2	Fresh	20.64 m^2	Fresh	20.44 m^2
Dry	7.56 m^2	Dry	17.96 m^2	Dry	17.72 m^2	Dry	17.52 m^2	Dry	16.24 m^2
Number of needle pairs/4 m^2		Number of needle pairs/4 m^2		Number of needle pairs/4 m^2		Number of needle pairs/4 m^2		Number of needle pairs/4 m^2	
79 949 pcs		210 560 pcs		179 933 pcs		203 720 pcs		232 680 pcs	

Fig. 3. Correlation between age class and the largest diameter of the branch base in selected transects (One age class means age range of 10 years. All dwarf pine ages in selected transects were at /or were approaching/ the upper limit of the age class)

cones. The total values were converted to an area of 1 ha (Table 4).

Figure 3 demonstrates correlation between the age class and the largest stem diameter of the branch base in selected transects. Figs 4 and 5 show the trend curves expressing the increasing biomass (mass and volume) based on age. The curves were used to create equations for the biomass calculation of dwarf pine stands of various age classes and canopy levels.

The equation for the calculation of the total fresh mass (t/ha):

$$y = 121.37e^{0.0052x}$$

The equation for the calculation of the large timber fresh mass (t/ha):

$$y = 1.8395e^{0.0313x}$$

in both equations: x = stand age.

The equation for the calculation of the total fresh mass volume (m^3/ha):

$$y = 81.838 \, Ln(x) + 86.386$$

The equation for the calculation of the large timber fresh mass volume (m^3/ha):

$$y = 0.0113x^2 - 0.0504x + 2.4725$$

in both equations: x = stand age.

Using these equations and the data regarding the distribution and cover of the dwarf pine, we estimated the biomass above the timberline of the Hrubý Jeseník Mts. The calculation shows that in the 360 ha area of the stands (of which 142 ha actually con-

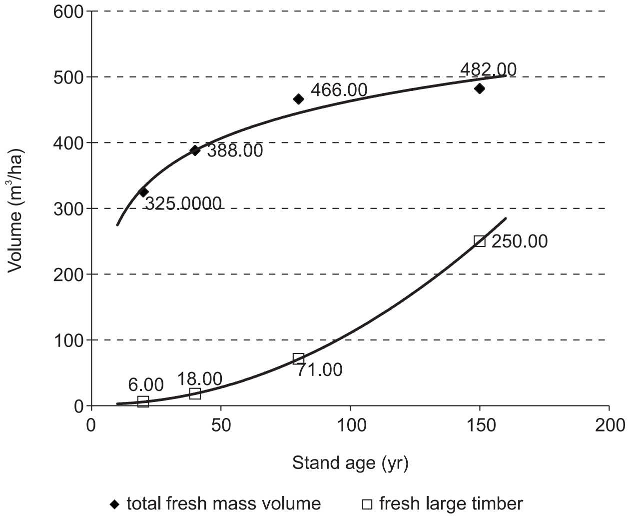

Fig. 5. Estimate of trends in the difference of volume (m^3/ha) of the aboveground dwarf pine biomass, dependent on increasing age

tain dwarf pines), there is 30 171 t and 66 325 m^3 of biomass, of which 9 892 t and 18 428 m^3 is large timber. The specific values calculated for individual segments of the dwarf pine stands, as defined by Šenfeldr et al. (2013), are presented in Table 5.

Discussion

Due to the scarcity of literature on the biomass of the dwarf pine, it is difficult to compare our results with those of other authors. Previously published information about dwarf pine biomass either relates to individual specimens (Popovic 1976) or individual branches (Špinlerová and Martinková 2006). Theoretically, it would be possible to calculate or estimate the number of dwarf pine specimens in the explored

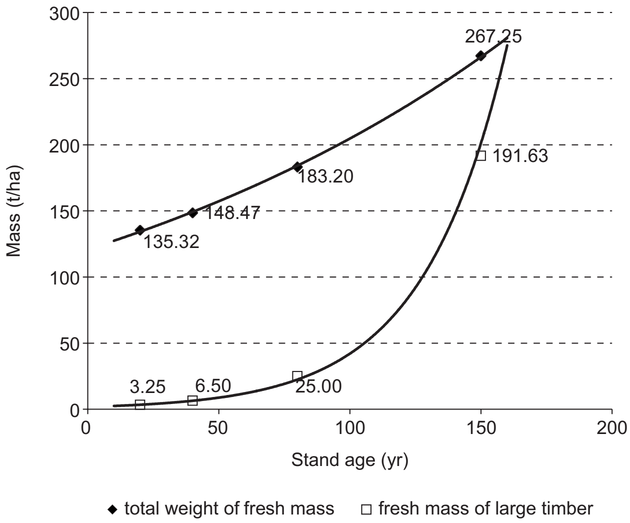

Fig. 4. Estimate of trends in the difference of mass (t/ha) of aboveground dwarf pine biomass, dependent on increasing age

Table 3. Parameters determined in selected transects converted to an area of 1 m^2

Transect K1 (≈ 150 yr)		Transect K2 (≈ 150 yr)		Transect K3 (≈ 80 yr)		Transect V1 (≈ 40 yr)		Transect V2 (≈ 20 yr)	
Height ≈ 2.5 m		Height ≈ 3.2 m		Height ≈ 1.3 m		Height ≈ 1.3 m		Height ≈ 1.2 m	
Fresh mass/m^2		Fresh mass/m^2		Fresh mass/m^2		Fresh mass/m^2		Fresh mass/m^2	
Large timber	15.000 kg	Large timber	23.325 kg	Large timber	2.5000 kg	Large timber	0.6500 kg	Large timber	0.3250 kg
Small timber	8.375 kg	Small timber	1.275 kg	Small timber	12.5250 kg	Small timber	10.7250 kg	Small timber	9.8000 kg
Needles	1.450 kg	Needles	3.625 kg	Needles	3.0500 kg	Needles	3.3500 kg	Needles	3.3750 kg
Cones	0.2 kg	Cones	0.2 kg	Cones	0.2500 kg	Cones	0.1220 kg	Cones	0.0325 kg
Total	25.025 kg	Total	28.425 kg	Total	18.3250 kg	Total	14.8470 kg	Total	13.5325 kg
Dry mass/m^2		Dry mass/m^2		Dry mass/m^2		Dry mass/m^2		Dry mass/m^2	
Large timber	10.15 kg	Large timber	15.95 kg	Large timber	1.7000 kg	Large timber	0.4000 kg	Large timber	0.1500 kg
Small timber	5.550 kg	Small timber	0.575 kg	Small timber	8.5250 kg	Small timber	6.3250 kg	Small timber	4.8000 kg
Needles	0.700 kg	Needles	1.625 kg	Needles	1.6250 kg	Needles	1.6000 kg	Needles	1.7000 kg
Cones	0.100 kg	Cones	0.105 kg	Cones	0.1330 kg	Cones	0.0605 kg	Cones	0.0162 kg
Total	16.500 kg	Total	18.255 kg	Total	11.9830 kg	Total	8.3855 kg	Total	6.6662 kg
Fresh mass volume/m^2		Fresh mass volume/m^2		Fresh mass volume/m^2		Fresh mass volume/m^2		Fresh mass volume/m^2	
Large timber	0.02 m^3	Large timber	0.03 m^3	Large timber	0.0071 m^3	Large timber	0.0018 m^3	Large timber	0.0006 m^3
Small timber	0.0100 m^3	Small timber	0.0025 m^3	Small timber	0.0259 m^3	Small timber	0.0194 m^3	Small timber	0.0153 m^3
Needles	0.0111 m^3	Needles	0.0228 m^3	Needles	0.0136 m^3	Needles	0.0176 m^3	Needles	0.0166 m^3
Total	0.0411 m^3	Total	0.0553 m^3	Total	0.0466 m^3	Total	0.0388 m^3	Total	0.0325 m^3
Needle area/m^2		Needle area/m^2		Needle area/m^2		Needle area/m^2		Needle area/m^2	
Fresh	2.09 m^2	Fresh	5.13 m^2	Fresh	5.41 m^2	Fresh	5.16 m^2	Fresh	5.11 m^2
Dry	1.89 m^2	Dry	4.49 m^2	Dry	4.43 m^2	Dry	4.38 m^2	Dry	4.06 m^2
Number of needle pairs/m^2		Number of needle pairs/m^2		Number of needle pairs/m^2		Number of needle pairs/m^2		Number of needle pairs/m^2	
19 987 pcs		52 640 pcs		44 983 pcs		50 930 pcs		58 170 pcs	

Jeseníky plots and compare the averages characterizing individual specimens with the results of other authors. However, this approach is unfeasible in practice because of the complicated growth of dwarf pines. Moreover, the ages of stands (individuals) or size parameters that are mentioned in the literature dealing with dwarf pine biomass are not exactly the same as the ages or size parameters of dwarf pine studied in selected transects. Other sources that mention the biomass of dwarf pine stands (e.g., Malinovskij 1984) cannot be used for comparison as they describe the values of natural communities without specifying size parameters. The dwarf pines in natural communities do not reach the same growth velocity and parameters as those in unnatural (and anthropogenically modified) sites.

The acquired values of the total fresh aboveground biomass converted to 1 ha (135–267 t/ha and 325–482 m^3/ha) in stands of the 2nd to the 15th age class may seem high. The reason for the large amount of biomass is the complicacy and the tenacity of pine polycormons. Moreover, the parameters presented in common forestry practice only concern large timber and not the entire aboveground mass. The values of the total aboveground biomass were calculated and are presented intentionally because of the current issue of complete dwarf pine mass removal and the further processing and use of the resulting materials.

The results of this study confirm the assumption that removing the biomass of the dwarf pines would not be an easy task. For example, the aboveground biomass of the oldest stands in the explored area,

Table 4. Basic data from the transect biomass converted to 1 ha

	Transect K1.K2 – average	Transect K3	Transect V1	Transect V2
Fresh mass of large timber/ha	191.625 t	25 t	6.5 t	3.25 t
Fresh mass of small timber/ha	48.25 t	125.25 t	108.8 t	98 t
Total weight of fresh mass/ha	267.25 t	183.20 t	148.47 t	135.32 t
Total weight of dry mass/ha	173.75 t	119.83 t	83.86 t	66.66 t
Fresh large timber volume/ha	250 m^3	71 m^3	18 m^3	6 m^3
Fresh small timber volume/ha	62.5 m^3	259 m^3	194 m^3	153 m^3
Total fresh mass volume/ha	482 m^3	466 m^3	388 m^3	325 m^3

Table 5. Biomass of selected segments. /As segments are defined areas of the dwarf pine stands growing above the timberline, which the authors of publication (Šenfeldr et al. 2013) delimited according to their consideration, eg. according to various canopy density./

Segment number	Stand area (ha)	Cover (%)	Reduced dwarf pine area (ha)	Age	Total biomass (t/1ha)	Total biomass in the total area (t)	Large timber (t/1ha)	Large timber (t) in the total area	Total biomass (m^3/1ha)	Total biomass (m^3) in the total area	Large timber (m^3/1ha)	Large timber (m^3) in the total area
1	5.9210	14.50	0.8585	90	28.1005	166.3831	4.4613	26.4153	65.9207	390.3167	12.9721	76.8083
2	27.5723	48.24	13.3006	90	93.4887	2577.7004	14.8424	409.2405	219.3144	6047.0043	43.1577	1189.9582
3	18.7325	27.60	5.0690	90	52.4431	982.3917	8.3260	155.9663	123.0259	2304.5838	24.2096	453.5069
4	1.8706	45.96	0.8598	90	89.0811	166.6351	14.1426	26.4553	208.9745	390.9078	41.1230	76.9246
5	14.9293	34.05	5.0837	80	62.6493	935.3111	7.6614	114.3803	151.5308	2262.2495	24.0951	359.7237
6	0.7993	55.68	0.4450	100	113.6653	90.8527	23.4274	18.7255	257.9360	206.1683	61.4866	49.1462
7	2.3815	42.01	1.0004	80	77.2846	184.0534	9.4512	22.50812	186.9294	445.1724	29.7239	70.7875
8	2.0058	45.45	0.9117	80	83.6252	167.7355	10.2266	20.5125	202.2655	405.7042	32.1625	64.5116
9	4.9797	46.89	2.3350	80	86.2713	429.6052	10.5502	52.5369	208.6655	1039.0919	33.1802	165.2276
10	6.7550	39.18	2.6465	80	72.0814	486.9101	8.8149	59.5448	174.3443	1177.6959	27.7227	187.2672
11	0.8384	29.90	0.2507	100	61.0373	51.1736	12.5803	10.5473	138.5094	116.1262	33.0177	27.6820
12	5.5382	51.31	2.8416	80	94.4011	522.8124	11.54443	63.9353	228.3293	1264.5335	36.3069	201.0754
13	3.1324	59.82	1.8737	80	110.0527	344.7293	13.4584	42.1573	266.1861	833.8014	42.3266	132.5840
14	2.5566	43.74	1.1181	80	80.4660	205.7196	9.8402	25.1577	194.6244	497.5767	30.9475	79.1204
15	1.0509	53.13	0.5583	110	114.2538	120.0693	30.5716	32.1277	250.2781	263.0172	71.0132	74.6278
16	1.1818	50.58	0.5978	110	108.7775	128.5532	29.1063	34.3978	238.2820	281.6016	67.6095	79.9009
17	6.9728	51.83	3.6137	80	95.3506	664.8613	11.6605	81.3067	230.6259	1608.1088	36.6721	255.7078
18	2.6885	26.27	0.7062	80	48.3283	129.9306	5.9101	15.8893	116.8923	314.2649	18.5872	49.9717
19	1.9848	27.61	0.5479	70	48.2186	95.7044	4.5421	9.0152	119.8353	237.8491	14.9946	29.7613
20	0.6325	60.75	0.3842	70	106.1001	67.1083	9.9944	6.3215	263.6849	166.7807	32.9941	20.8688
21	1.6321	56.3	0.9189	70	98.3381	160.4977	9.2633	15.1186	244.3947	398.8766	30.5804	49.9103
22	1.3356	64.21	0.8576	70	112.1555	149.7949	10.5648	14.1104	278.7343	372.2775	34.8772	46.5820
23	0.5251	32.68	0.1716	70	57.0788	29.9721	5.3767	2.8233	141.8550	74.4880	17.7499	9.3204
24	1.2284	55.98	0.6877	40	83.6596	102.7675	3.6017	4.4243	217.3765	267.0254	10.3776	12.7479
25	3.9688+ 0.4410	57.13	2.2675+ 0.2519	80;170	111.3847	491.1845	33.0695	145.8302	257.7594	1136.6674	54.6927	241.1842
26	5.4565+ 0.9629	71.58	3.9508+ 0.6893	70;80	147.9426	949.7028	13.9359	89.4606	367.6739	2360.2461	46.0060	295.3309
27	0.2981	49.47	0.1475	80	91.0096	27.1299	11.1296	3.3177	220.1261	65.6196	35.0026	10.4342
28	0.8056	36.39	0.2932	80	66.9547	53.9387	8.1879	6.5962	161.9443	130.4623	25.7510	20.7450
29	1.3712	39.04	0.5353	80	71.8306	98.4942	8.7842	12.0449	173.7377	238.2292	27.6263	37.8812
30	0.5425	61.96	0.3362	80	114.0023	61.8462	13.9414	7.5632	275.7389	149.5884	43.8456	23.7862
31	5.9345	14.12	0.8381	40	21.1028	125.2347	0.9085	5.3915	54.8324	325.4029	2.6177	15.5348
32	10.932	39.35	1.43396+ 1.43396+ 1.43396	120;130;170	99.5494	1088.2747	73.8025	806.8091	192.7725	2107.3900	87.4278	955.7610
33	0.3026	14.15	0.0428	120	32.0606	9.7015	11.1370	3.3700	67.6794	20.4797	22.5243	6.8158
34	0.3249	44.45	0.1444	120	100.6998	32.7173	34.9806	11.3652	212.5755	69.0658	70.7472	22.9857
35	3.8284	24.12	0.9236	120	54.6460	209.2068	18.9826	72.6732	115.3568	441.6320	38.3918	146.9793
36	1.5991	16.20	0.12805+ 0.12805	110;160	39.5587	63.2584	26.6484	42.6135	77.9089	124.5842	33.4244	53.4490
37	3.6188+ 0.4021	53.33	2.0370+ 0.1072	110;160	116.3776	467.9428	36.4869	146.7104	252.0188	1013.3424	75.2751	302.6737
38	16.7253	36.47	6.0991	120	82.6045	1381.5859	28.6947	479.9286	174.3767	2916.5035	58.0342	970.6405

Segment number	Stand area (ha)	Cover (%)	Reduced dwarf pine area (ha)	Age	Total biomass (t/1ha)	Total biomass in the total area (t)	Large timber (t/1ha)	Large timber (t) in the total area	Total biomass (m³/1ha)	Total biomass (m³) in the total area	Large timber (m³/1ha)	Large timber (m³) in the total area
39	18.3442	43.69	8.0151	120	98.9744	1815.6065	34.3812	630.6966	208.9332	3832.7135	69.5350	1275.5640
40	5.2887	40.63	2.1488	120	92.0378	486.7605	31.9716	169.0885	194.2902	1027.5430	64.6616	341.9762
41	9.3060	27.62	2.5703	120	62.5652	582.2322	21.7336	202.2530	132.0741	1229.0820	43.9555	409.0503
42	3.4013	57.95	1.9710	120	131.2676	446.4807	45.5991	155.0963	277.1037	942.5130	92.2228	313.6774
43	1.6357	41.73	0.6826	120	94.5354	154.6316	32.8392	53.7152	199.5627	326.4247	66.4164	108.6373
44	3.3639	61.74	2.0770	120	139.8626	470.4838	48.5848	163.4344	295.2475	993.1831	98.2612	330.5409
45	2.0115	49.96	1.0049	120	113.1710	227.6435	39.3128	79.0777	238.9020	480.5514	79.5089	159.9321
46	3.4062	10.67	0.3634	120	24.1685	82.3230	8.3956	28.5969	51.0194	173.7824	16.9797	57.8364
47	8.6907	16.41	1.4265	150	43.4591	377.6900	33.0317	287.0693	81.4876	708.1851	40.8980	355.4325
48	1.1005	37.77	0.4157	160	105.3476	115.9350	103.9505	114.3976	189.5172	208.5637	107.1573	117.9266
49	2.2979	33.22	0.7633	120	75.2477	172.9118	26.1392	60.0652	158.8467	365.0139	52.8657	121.4801
50	6.8696+ 0.3616	38.08	2.6157+ 0.1377	50;130	89.3082	645.8055	39.0914	282.6778	183.0789	1323.8803	68.1389	492.7266
51	17.5583	59.14	10.3846	110	127.1851	2233.1543	34.0317	597.5395	278.6046	4891.8234	79.0505	1387.9937
52	1.5698	39.25	0.6161	130	93.6446	147.0034	42.2311	66.2944	190.2363	298.6329	73.3459	115.1384
53	3.2894	55.21	1.8162	130	131.7459	433.3652	59.4137	195.4355	267.6378	880.3680	103.1882	339.4273
54	7.3901	28.83	2.1306	130	68.7924	508.3828	31.0234	229.2664	139.7496	1032.7639	53.8807	398.1838
55	0.1689	32.54	0.0550	130	77.6518	13.1154	35.0188	5.9146	157.7474	26.6435	60.8197	10.2725
56	0.2793	21.42	0.0598	130	51.1192	14.2776	23.0533	6.4388	103.8472	29.0045	40.0384	11.1827
57	2.8517	25.66	0.7317	130	61.2262	174.5988	27.6113	78.7391	124.3791	354.6921	47.9546	136.7521
58	2.4636+ 2.0156	49.45	0.7383+ 1.4767	80;130	108.9906	488.1910	39.1838	175.5124	233.1551	1044.3483	73.2761	328.2185
59	5.9671	13.00	0.7755	130	31.0089	185.0336	13.9841	83.4450	62.9937	375.8901	24.2873	144.9250
60	2.0348	48.48	0.9865	150	128.3624	261.1919	97.5639	198.5231	240.6851	489.7461	120.7979	245.7997
61	2.4333	69.15	1.6826	150	183.0772	445.4819	139.1508	338.5956	343.2777	835.2978	172.2884	419.2293
62	1.6084	67.09	1.079	150	177.6185	285.6817	135.0018	217.1369	333.0425	535.6656	167.1514	268.8463
63	3.1381	20.62	0.6472	150	54.6036	171.3515	41.5023	130.2385	102.3841	321.2915	51.3857	161.2537
64	4.5805	72.77	3.3333	80	133.8876	613.2721	16.3732	74.9978	323.8357	1483.3295	51.4936	235.8665
65	5.2401	34.06	1.7845	130	81.2611	425.8165	36.6465	192.0313	165.0795	865.0331	63.6466	333.5149
66	6.2199	86.13	5.3572	80	158.4635	985.6271	19.3786	120.5335	383.2777	2383.9495	60.9455	379.0754
67	8.2506	26.34	2.1728	130	62.8399	518.4674	28.3390	233.8143	127.6574	1053.2505	49.2185	406.0825
68	7.9555	24.30	1.9335	130	57.9937	461.3691	26.1535	208.0646	117.8124	937.2572	45.4228	361.3611
69	4.8065	36.47	1.7529	130	87.0193	418.2585	39.2433	188.6229	176.7771	849.6793	68.1567	327.5952
70	1.6335	24.00	0.3921	130	57.2724	93.5544	25.8282	42.1904	116.3471	190.0530	44.8578	73.2752
71	6.8182	31.27	2.1322	110	67.2486	458.5146	17.9941	122.6877	147.3111	1004.3965	41.7976	284.9849
72	2.8970+ 0.9657	22.53	0.8617+ 0.0087	110;170	48.6342	187.8595	13.6839	52.8570	106.2272	410.3239	30.5386	117.9616
73	0.9351+ 1.1429	38.79	0.5240+ 0.2821	170;110	103.2755	214.6066	102.7115	213.4345	191.7191	398.3924	98.9575	205.6337
74	1.9053+ 1.1432+ 0.7621	45.55	1.0414+ 0.4339+ 0.2603	170;140;110	121.9441	464.6802	119.4541	455.1918	225.6380	859.8163	117.6178	448.1947
75	1.1631+ 5.8153+ 4.6522	12.55	0.2918+ 0.4378+ 0.7296	40.140.170	31.6397	367.9896	29.3088	340.8798	60.0013	697.8520	28.7332	334.1844
Total	360.4923					30 170.8433		9 891.8493		66 325.37702		18 427.6614

consisting of complicated and tenacious polycormons of the dwarf pine, is comparable to the large timber of a mature spruce stand that is ready to be felled. For example, Corona et al. (2011) mention that in the Czech Republic and other European countries the greatest per-ha deadwood levels are observed in mountain regions. This cannot be explained solely in terms of favorable ecological growing conditions; rather, it is likely linked to the poor accessibility and thus low intensity of forest harvesting. The dwarf pine cutting in these conditions can therefore be problematic due to the complexity of handling and disposal of such quantities of biomass (poor availability of human resources, financial demands, far availability of funds and also legislative context).

Corona et al. (2011) point out that in order to facilitate future research should serve large-scale forest inventories, such as National Forest Inventories. This should expand from traditional variables related to wood and timber production to the assessment of the composition, structure and function of forest ecosystems, and must provide a better understanding of the roles of the components of biological diversity in the provision of multiple forest ecosystem functions. It must result in well-developed partnership among ecologists, nature conservationists, statisticians, resource managers and policymakers (Lindenmayer et al. 2008; Gibbons et al. 2008). Partnerships and compromise among all entities dealing with management of dwarf pine in Hrubý Jeseník Mts. (the Forests of the Czech Republic, State Enterprise, the Administration of the Protected Landscape Area Jeseníky, entities conducting its monitoring and research) in this case are very important.

Conclusion

Dwarf pines planted on non-indigenous mountainous sites are currently a frequent topic of professional discussions and the summits of the Hrubý Jeseník Mts. in the Czech Republic are no exception. In response to various proposals for dwarf pine reduction, we estimated the amount of aboveground biomass that is located above the timberline in the mountains.

The main result is a methodology for dwarf pine biomass determination that can be used for acquisition and addition of further data, also new trend curves expressing the increasing biomass in relation to age and the creation of equations that could be used to roughly estimate the biomass of all dwarf pine stands, including stands of different age classes and canopy levels on mentioned sites above the timberline. The equations for biomass calculations could also be applied to other mountain ranges where artificially planted dwarf pines of the same seed origin or the same morphological appearance as those existing in the Hrubý Jeseník Mts. are found.

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