Estimating aboveground biomass for Norway spruce (*Picea abies*) in Iceland

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ABSTRACT

Forest carbon sinks were included in the Kyoto Protocol as an option for mitigating climate change, since these sinks are known to play an important role in the global GHG balance. Therefore all countries that have ratified the Kyoto Protocol need to deliver estimates of forest area and carbon stocks to UNFCCC. This work presents the results of a study of Norway spruce in Iceland. The aim was to compare two methods to estimate forest biomass and carbon stocks, either directly with biomass equations or indirectly from stem volume, basic density and biomass expansion factors (BEFs). Basic wood density of Norway spruce was significantly related to tree size ($P<0.002$), but BEF showed no such relation. The two methods gave significantly different estimates for stem biomass, with the direct allometric method giving better results when compared to real values. There was, however, no significant difference between the two methods when total aboveground biomass was estimated. The direct allometric method will therefore be used to estimate the carbon stock of Norway spruce stands in Iceland, since it involves fewer parameters than the BEF method.

Keywords: BEF, biomass expansion factors, carbon stock, forest inventory, Iceland, Kyoto protocol, *Picea abies*

YFIRLIT

*Tvær ólíkar aðferðir til að áætla lífmassa rauðgrenis (*Picea abies*) ofan foldu út frá skógvaxtarmælingum*

Nú þegar Alþingi Íslendinga hefur staðfest Kyotosamninginn verða stjórnvöld að standa skil á útreikningum á kolefnisforða allra skóglenda landsins til Sameinuðu þjóðanna. Þetta kallar eftir aukinni áherslu á að þróa traustar aðferðir við slíkt mat. Í þessari rannsókn voru bornar saman tvær ólíkar aðferðir við að meta lífmassa, og þar með kolefnisforða rauðgrenis. Annarsvegar var útbúin líking sem gerði kleift að meta lífmassa ofanjarðar beint út frá mælingum á hæð og bolþvermáli. Hinsvegar var notuð líking sem fyrst mat bolrúmmál út frá skógvaxtarmælingum, því var síðan umbreytt í lífmassa ofanjarðar með því að margfalda það með rúmþyngd viðar og greinahlutfalli. Rúmþyngd (viðarþéttleiki) rauðgrenis reyndist vera marktækt tengd stærð eða aldri trjánna. Útbúin var líking sem áætlaði rúmþyngd viðar miðað við bolrúmmál trjánna. Hlutfall greina og barrs miðað við bolmassa reyndist vera stöðugt og óháð stærð og aldri. Báðar aðferðirnar gáfu nokkuð traust mat á lífmassa stofns og heildarlífmassa ofanjarðar, en óbeina aðferðin vanmat þó marktækt lífmassa stofns miðað við beinu lífmassalíkinguna. Við mat á lífmassa og kolefnisforða íslenskra skóglenda munu verða notaðar beinar lífmassalíkingar.

INTRODUCTION

This work was initiated by the Nordic research project "Estimation of carbon storage in forest biomass in the Nordic and Baltic countries - common methods, protocol and tools for obtaining comparable biomass expansion functions (BEF)", funded by the Nordic Forest Research Co-operation Committee (SNS) in 2004-2006. This project is co-ordinated by the Danish Forest and Landscape Research Institute. All the Nordic and Baltic countries participate in the project, with representatives from the Estonian Agricultural University, Finnish Forest Research Institute (METLA), Icelandic Forest Research, Latvian Forestry Research Institute, Lithuanian Forest Research Institute, Norwegian Skogforsk, Agricultural University of Norway, Swedish SkogForsk, and Swedish University of Agricultural Sciences.

In order to fulfil the obligations of the Kyoto Protocol, good and verifiable estimates of carbon pools and sequestration in forest biomass are needed (UNFCCC 1998). To estimate the national carbon pool, forest inventory data on merchantable fresh stem volume are usually converted to total biomass in stems, branches and foliage and even root mass (Lehtonen *et al.* 2004). These conversions from volume to mass are recognised as an important source of uncertainty in estimation of carbon storage in forest biomass (cf. Löwe *et al.* 2000). However, direct comparisons between different methods and background data remain scarce (Lehtonen *et al.* 2004).

It was decided that a good starting point for this Nordic project was to focus on how to estimate above- and belowground carbon pools in Norway spruce (*Picea abies* (L.) Karst.) stands, a species common to most of the participating countries. Contrary to the other Nordic countries, Norway spruce is not an important species in Icelandic forestry. It only accounts for 6% of tree seedlings planted in the past century (Pétursson 1999). Therefore there has been less emphasis on establishing volume and biomass functions for this species than the much more often planted Siberian larch (*Larix sibirica* Ledeb.), native mountain birch (*Betula pubescens Ehrh*.), Sitka spruce (*Picea sitchensis* (Bong) Carrière) and lodgepole pine (*Pinus contorta* . Dougl. ex Loud.). These are the four most planted species in Iceland and in the order given above.

Two main types of models can be used for estimating aboveground biomass from individual tree measurements or inventory data: (1) allometric biomass equations or (2) stem volume equations, basic density and biomass expansion factors (BEFs). Biomass expansion factors are constants that convert stem volume or mass to whole tree biomass. They may be developed into functions by including relationships with age or tree size (Lehtonen *et al.* 2004).

This work presents the results of a study on Norway spruce in Iceland. The aim was to determine the basic wood density and BEF to be able to estimate the aboveground biomass of single trees, based on their stem volume. The results were then compared with allometric biomass estimations prepared by Snorrason & Einarsson (2004) and measured values.

MATERIALS AND METHODS

Harvest measurements

The 16 sample trees used for the calculations were harvested in various locations in Iceland as a part of a larger study aiming to create allometric equations for stem volume and a number of aboveground biomass compartments (Figure 1, Snorrason & Einarsson 2004). Suitable sample plots were selected from all existing measurement plots within Norway spruce stands of varying age. Trees on each plot were classified into basal area classes. Harvest trees were randomly chosen so that they were evenly distributed among basal area classes and had a countrywide distribution. The initial goal was to harvest 28 Norway spruce trees. However, in the harvesting process the total number of trees harvested decreased to 16, mostly due to a loss of trees in the highest basal area classes. The main reasons for loss of harvest trees were that owners did not permit destructive sampling or the selected trees were judged not to represent the measurement plot (e.g. severely damaged individuals). Snorrason & Einarsson (2004) present further information on the sampling.

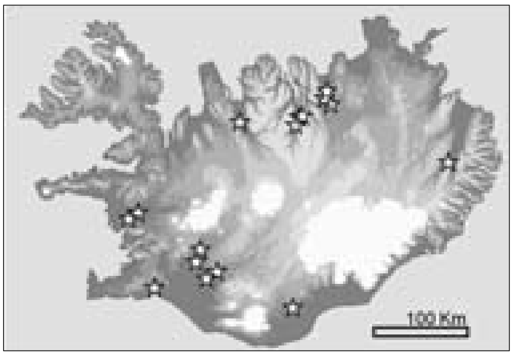

Figure 1. A map of Iceland showing the location of measurement plots where the 16 Norway spruce trees were harvested. See Table 1 for more information.

At harvest, the stem of each sample tree was divided into three equally long sections. The average basal area was calculated for each section, and one 3 cm thick stem disk was taken at the site of the average basal area in each stem section. When sample trees had more than one main stem in a height section, a disk was taken from each main stem.

Stem volume over bark by allometric function

The following allometric stem volume equation presented in Snorrason & Einarsson (2004) was used:

$$V = 0.1299 \times D^{1.6834} \times H^{0.8598}, \quad (1)$$

where V is stem volume over bark in dm^3, D is diameter at breast height (1.3 m) in cm and H is tree height in m. Equation 1 accurately fitted the measured values for the 16 sample trees ($r^2=0.99$, $P<0.001$).

Basic density measurements

The smaller disks were used whole as a wood sample, but for the larger disks, a slice was cut from the disk. Care was taken always to cut to the pith of the disk when a slice was taken. The samples were first dried at 80 °C for ca. 48 hours and weighed. Then the water displacement method (Olesen 1971, Sigurdsson 2001) was used to measure their volume. First the disks were submerged in water with 0.02% detergent for approximately 56 hours to saturate the dried wood with water. The detergent decreased surface tension and let water penetrate the dried samples more easily. Volume was then measured by submerging the samples, which were fixed to a steel needle, in a container filled with deionised water that was placed on a scale. As the samples were carefully submerged, the water column in the container rose. Hence, its mass increased because of the gravitational force that increased with the increasing water volume. If the volume of the deionised water increased by one cm^3, then its mass increased by one gram. The basic wood density was thereafter calculated as $g\ cm^{-3}$. The bark was then removed from the samples, and the new basic density measured after the samples had been submerged for 24 hours in the detergent solution and then dried again for 72 hours and weighed.

Stem mass by allometric function

An alternative method, an allometric biomass equation, was also used to estimate the stem mass over bark. The equation used for Norway spruce was parameterised by Snorrason & Einarsson (2004):

$$M_{stem} = 0.0712 \times D^{1.637} \times H^{0.7436}\ , (2)$$

where M_{stem} is stem mass including bark in kg, D is diameter at breast height (1.3 m) in cm and H is tree height in m. This function was found to give accurate estimates of stem mass when compared with the true stem mass found by weighing (r^2=0.97 and P<0.001).

Biomass Expansion Factor

To estimate the aboveground biomass of a whole tree from stem volume and basic density, a biomass expansion factor (BEF) was estimated for the 16 sample trees. The BEF was calculated as the ratio between the total aboveground biomass (M_{total}; biomass above stump, including living branches, foliage and dead branches) and the stem biomass (M_{stem}; biomass above stump, including bark):

$$\mathrm{BEF} = \frac{M_{total}}{M_{stem}}\ , (3)$$

Total aboveground biomass estimated with an allometric function

An allometric biomass function, previously found by Snorrason & Einarsson (2004), was used to directly estimate total aboveground biomass. The equation used was:

$$M_{total} = 0.2465 \times D^{2.120} \times H^{-0.167}, (4)$$

where M^{total} is total aboveground biomass in kg, and D and H are diameter at breast height in cm and tree height in m, respectively. Equation 5 was found to give accurate estimates of total aboveground biomass when compared with the true total aboveground biomass found by weighing (r^2=0.95 and P<0.001).

Table 1. Main characteristics of Norway spruce sample trees. H is tree height, D ob is diameter at breast height (1.3 m) over bark, BT is bark thickness, Vol is stem volume over bark, TBIO is total aboveground biomass and the relative mass fractions; S, DB, B and N are stem, dead branches, living branches and needles, respectively. Locations are also shown in Figure 1.

Location in Iceland	No	H (m)	D ob (cm)	BT (mm)	Vol (dm^3)	TBIO (kg)	Relative aboveground dry matter S	DB	B	N
Ytra-Fjall	1	2.7	2.70	1.7	1.9	1.9	0.44	0.03	0.18	0.35
Holtsdalur	2	4.2	5.45	1.6	7.0	6.5	0.47	0.04	0.26	0.24
Álfaborgir	3	6.1	9.65	3.3	25.8	22.9	0.50	0.26	0.17	0.07
Einkunnir	4	5.2	10.75	2.7	27.3	27.3	0.48	0.05	0.22	0.25
Daníelslundur	5	7.0	12.85	3.3	47.4	41.1	0.43	0.05	0.28	0.23
Laugarból	6	7.8	12.50	2.5	48.5	25.8	0.62	0.05	0.20	0.13
Stóri Núpur	7	8.4	13.85	2.1	60.3	40.1	0.54	0.07	0.24	0.14
Hallormsstaður	8	9.9	13.70	2.3	83.5	45.5	0.65	0.01	0.17	0.17
Grund	9	9.6	18.00	2.5	98.3	64.0	0.56	0.11	0.19	0.15
Reykjarhóll	10	8.3	16.55	1.9	103.8	61.9	0.57	0.03	0.23	0.16
Vatnsleysa	11	12.0	16.55	2.3	126.7	79.1	0.70	0.04	0.18	0.08
Thjórsárdalur	12	10.8	18.40	2.6	138.5	69.2	0.68	0.04	0.14	0.14
Fossselsskógur	13	8.7	20.60	3.3	151.3	140.5	0.36	0.01	0.39	0.23
Haukadalur	14	10.3	20.35	5.2	159.9	100.7	0.56	0.05	0.26	0.14
Kristneshæli	15	8.7	21.85	4.0	160.2	114.1	0.49	0.00	0.35	0.16
Gardsárgil	16	10.7	27.90	4.4	271.2	203.4	0.55	0.03	0.23	0.19
Min		2.7	2.7	1.7	1.9	1.9	0.43	0.00	0.14	0.07
Max		12.0	27.9	5.2	271.2	203.4	0.70	0.26	0.39	0.35
Average		**8.2**	**15.1**	**2.8**	**94.5**	**65.3**	**0.54**	**0.06**	**0.23**	**0.18**
SE		*0.6*	*1.6*	*0.2*	*17.9*	*13.3*	*0.02*	*0.02*	*0.02*	*0.02*

RESULTS AND DISCUSSION

Iceland has proportionally the smallest woodland cover of Europe, a mere 1.3% of total surface area. Most of this is remains of the native birch woodlands (*B. pubescens*). Forest plantations presently cover ca. 0.2% of the total surface area, or ca. 20,000 ha (Sigurdsson & Snorrason 2000). Approximately 6% of tree seedlings planted in the past century were Norway spruce (Pétursson 1999), which indicates that this species now covers ca. 1000 ha in Iceland. Even if forests and plantations are not extensive, Icelandic authorities need to report all changes in their cover and carbon stock to the United Nations.

This work was a part of a larger study aiming at improved estimates of forest biomass and carbon stock in Icelandic woodlands (Snorrason & Einarsson 2004). The sample trees chosen ranged from 2.7 to 12 m in height and 2.7 to 28 cm in diameter at breast height (Table 1). It should be noted that the relationships given in this paper may not be valid for trees outside this size range.

Basic density measurements

The average and standard error of all basic density measurements was 0.36 ±0.01 g cm^{-3}, for wood samples both with and without bark (Figure 2). The density of the Icelandic trees seemed a little lower than generally has been found for Norway spruce; 0.38-0.40 g cm^{-3} in Sweden (Hakkila 1979, Kostiainen *et al.* 2004), 0.40 g cm^{-3} in Belgium (Perrin *et al.* 2000), and 0.385 g cm^{-3} in Finland (Tomppo 2000). However, the German National Inventory uses a similar basic density for Norway spruce, 0.37 g cm^{-3} (Baritz & Stitch 2000). There even exist some lower density values for Norway spruce, e.g., 0.32 g cm^{-3} from Italy (Romagnoli *et al.* 2003) and 0.31 g cm^{-3} from Swedish abandoned farmland (Johansson 1999). Oksbjerg (1971) reported a basic density of 0.45, 0.42 and 0.39 for Danish Norway spruce trees with 10, 15 and 20 cm DBH, respectively. All these values are within the range of basic density found for Norway spruce trees of different nutritional status in a long-term fertilisation experiment in northern Sweden, 0.31-0.41 g cm^{-3} (Bergh *et al.* 1999). Lower basic density values are typically found at higher fertility (Bergh *et al.* 1999; Anttonen *et al.* 2002; Kostianinen *et al* 2004), which may be the case for the Icelandic, Italian, Danish and German conditions.

The basic density in the present study varied somewhat along the stem, with an average and a standard error of 0.36 ±0.02, 0.34 ±0.01 and 0.39 ±0.01 g cm^{-3} in the bottom, middle and top thirds, respectively (Figure 2). There was a significantly higher basic density in the top compared to the middle third of the stem (t-test, $P<0.01$), but the top was not significantly different from the bottom third. The same significant trend was found along the stem for samples without bark. The average and standard error of basic density without bark was 0.35 ±0.02, 0.34 ±0.01 and 0.38 ±0.01 g cm^{-3} in the bottom, middle and top thirds of the stem, respectively. Koga and Zhang (2004) showed a similar height pattern for basic densi-

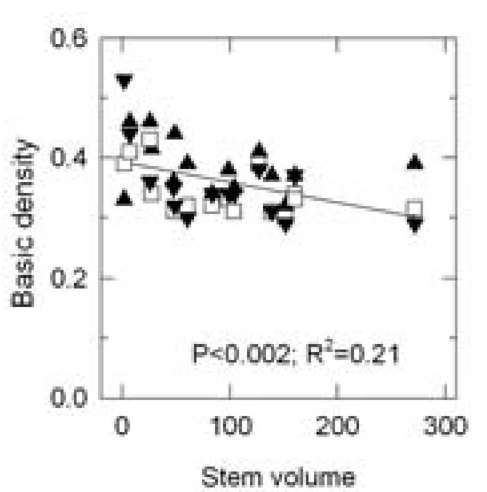

Figure 2. Basic wood density (g cm^{-3}; including bark) at three heights (▲ = top third, □ = middle third and ▼ = bottom third) as a function of tree stem volume (dm^3). Stem disks were sampled from 16 Norway spruce trees growing all around Iceland.

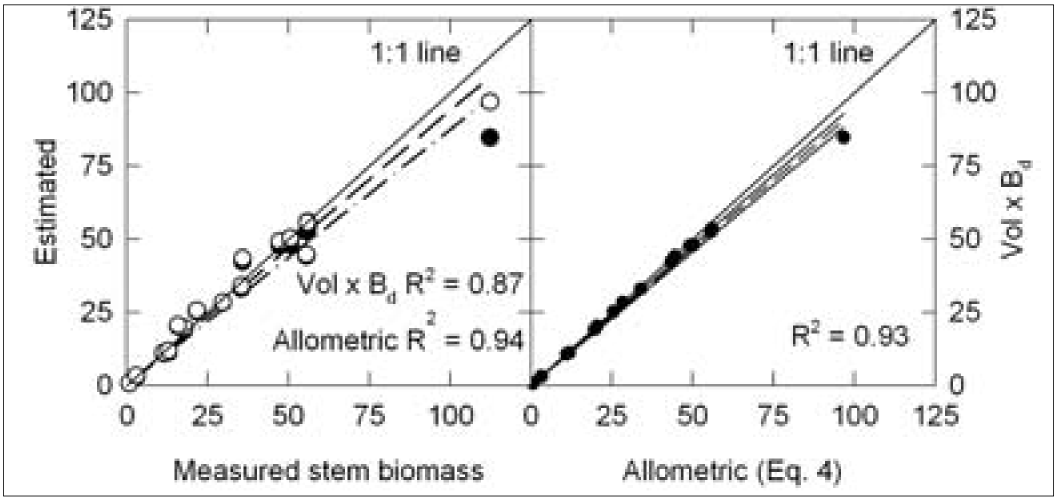

Figure 3. Stem biomass over bark (kg) estimated by two methods (left panel) for the 16 Norway spruce trees vs. measured values for the same trees. (○) stem mass estimated by the direct method (allometric biomass equation) and (●)stem mass estimated by the indirect method (estimated stem volume converted to mass). Also shown are the two estimates plotted against each other (right panel), and their linear relationship and its 95% confidence interval.

ty within balsam fir trees (*Abies balsamea* (L.) Mill.) in Canada.

There was also a significant relationship between size of the tree and its average basic wood density (Figure 2; regression analysis, $P<0.002$, $r^2=0.21$):

$$B_d = 0.3933–0.0003V\ , (5)$$

where B_d is basic stemwood density including bark in g cm^{-3} and V is stem volume over bark in dm^3. This relationship indicates that the smallest trees had a basic density of 0.39 g cm^{-3}, but as the stem volume increased by 100 dm^3, the average basic density decreased by 0.03 g cm^{-3}. A similar size- or age-dependent decrease of B_d has been noted for balsam fir (Koga & Zhang 2004) and Norway spruce younger than 50 years (Hakkila 1979). However, when Norway spruce was older than 50 years and its stem volume had increased past what was found in the present study, its B_d started to increase again (Hakkila 1979).

Stem mass estimated from Bd

Basic density was used with Equation 1 and measurements of DBH and height to estimate stem mass of the sample trees (Figure 3). Note that the basic density value 0.3933 g cm^{-3} can also be written 0.3933 kg dm^{-3}. All data for basic wood density and biomass estimates are found in Appendix 1.

It is noteworthy that when basic wood density was multiplied by measured stem volume, the estimated stem mass was not significantly different from the true values for the 16 sample trees (Mean tree estimate 34.2 ±6.5 kg when the true value was 35.2 ±7.0, $P=0.45$). This clearly shows that the water displacement method on pre-dried wood samples gave accurate basic density values and further supports the use of this simple method (Sigurdsson 2001).

Stem mass estimated by two functions

The results from the two methods of estimating stem biomass are presented and compared to true measured values in Figure 3. Both methods gave relatively good estimates of stem biomass over bark when compared to measured values (Figure 3, $r^2>0.87$ and 0.94, $P<0.001$). Smaller trees fell close to the 1:1 line, but as the trees became larger stem biomass was slightly underestimated by both methods (Figure 3, left panel). This was probably due to the lack of larger trees in the sample, a natural problem in a country where the first forest plantation was only established in year 1899 (Blöndal & Gunnarsson 1999). However, the two methods gave significantly different estimates of stem mass, indicated by the 95% confidence interval of the linear regression of their estimates moving away from the 1:1 line (Figure 3, right panel). The direct allometric method (Equation 2) gave better results than the indirect method that involved both estimates of stem volume and basic density (Equations 1 and 5). As was noted by Brown (1997), this should be expected since the indirect method involves more assumptions than the direct allometric method, which estimates biomass directly from diameter and height measurements.

It is both a limitation and strength of the present analysis that all calculations were based on the same 16 sample trees: strength when it came to analysing the accuracy of different methods, but a limitation for knowing how general the methods are. Ideally a third comparison should be made, with the two methods used to estimate stem mass of an independent sample of trees that has been weighed. Unfortunately that dataset does not yet exist.

Total aboveground biomass

The results presented so far have only included the stem, when the main goal of the project was to compare estimates of aboveground biomass of the trees (M_{total}).

The indirect method used in this analysis was an extension of the indirect basic density method for estimating stem biomass (Equations 1 and 5), where a biomass expansion factor (BEF) was added. The average BEF of the 16 sample trees was 1.92 (Figure 4). This value is close to the average BEF used for Norway spruce by the Finnish National Inventory (1.86; Tomppo 2000), but higher than the average BEF used by the German National Inventory (1.45, Baritz & Strich 2000) and the Swedish national reporting to EU (1.30, Löve *et al.* 2000).

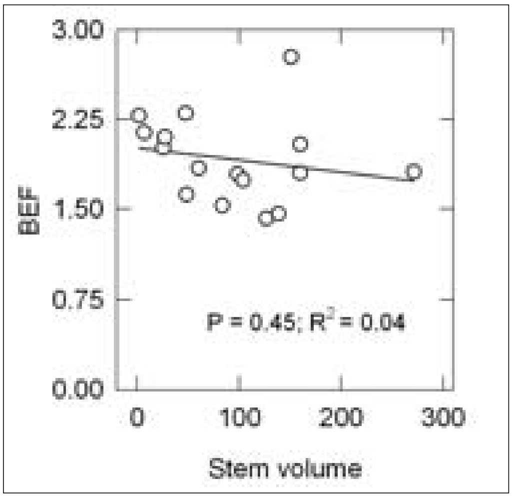

Figure 4. Relationship between biomass expansion factor (BEF) and stem volume over bark for 16 Norway spruce sample trees growing all around Iceland.

A size-dependent pattern in BEF could be expected, similar to what was found for basic wood density. Such patterns have been reported by Lehtonen *et al.* (2004) and Kauppi *et al.* (1995). These results have been explained by the fact that young and small trees usually contain relatively more biomass in branches and foliage than larger and older trees. When trees grow older and canopies become closed, the stems continue to accumulate dry matter, but as new branches and foliage are grown the oldest die and fall off (Kauppi *et al.* 1995). However, in the present analysis, no such size-dependent pattern emerged for BEF of Norway spruce (Figure 4). The regression between individual tree BEF and stem volume was not significant and only explained 4% of the variability found in the BEFs (Regression analysis; $P=0.45$, $r^2=0.04$). Therefore, the average BEF of 1.92 was used for all the Norway spruce trees to estimate their total aboveground biomass in the present study.

Figure 5 shows a comparison between measured aboveground tree biomass and the two

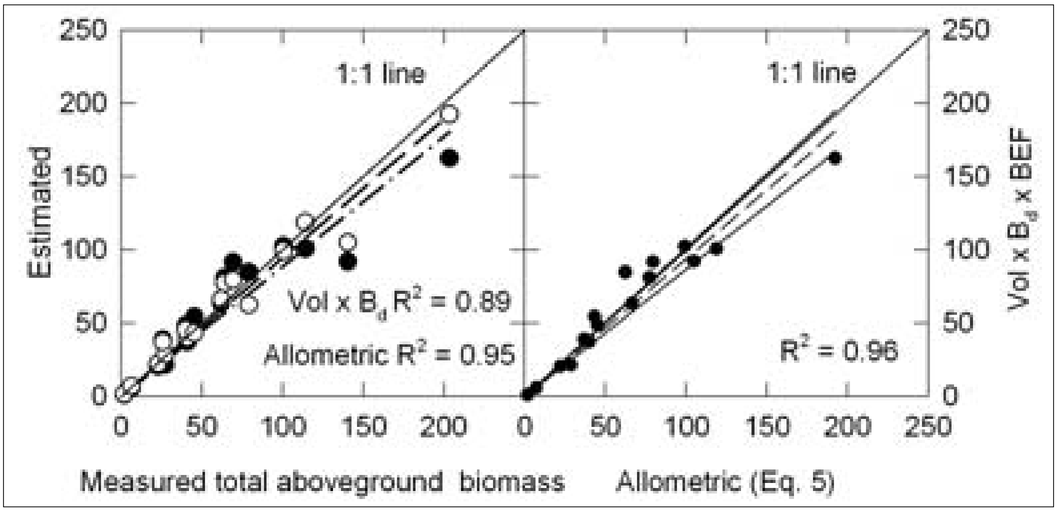

Figure 5. Total aboveground biomass of 16 Norway spruce trees estimated by two methods (left panel) vs. measured values for the same trees. ○ are total aboveground mass estimated by the direct method (allometric biomass equation) and ● are estimates by the indirect method (estimated stem volume converted to total aboveground biomass). Also shown are the two estimates plotted against each other (right panel), their linear relationship and its 95% confidence interval.

estimation methods used. Both methods gave relatively good estimates of total aboveground biomass when compared to true measured values (Figure 5, $r^2>0.89$ and 0.95, $P<0.001$). There was, however, more scatter in the M_{total}-estimates than was observed for stem biomass (Figure 3). The largest deviations for both methods occurred for the second largest sample tree, which had a relatively higher branch fraction than the other trees. It may be speculated that it was growing closer to a forest edge or an opening than the other sample trees and therefore had more foliage and branches.

Even if the indirect method gave on average a 4% lower estimate of total aboveground biomass than the allometric method, the 95% confidence interval encompassed the 1:1 line (Figure 5, right panel). Hence, there were no significant differences between total aboveground biomass estimated by the two different methods. The indirect method can be as accurate when good information exists about basic density and BEF.

The direct method, using allometric equations giving the biomass directly from measurements of diameter and height, is often considered the preferred method if accurate equations are available, which is not the case in most countries (Brown 1997). The reason that many countries still prefer to use the indirect method to estimate national forest biomass and carbon stock is that often there exist much better equations to estimate stem volume than biomass (Brown 1997, Lehtonen *et al.* 2004). However, since Snorrason & Einarsson (2004) have derived allometric biomass functions for all the most commonly used tree species in Iceland, the use of these functions are the preferred method to estimate forest biomass and carbon stock, rather than the more cumbersome and complex BEF-method, which involves more parameters.

To be able to convert total biomass to carbon stock, the average carbon concentration of wood, bark and foliage needs to be known. Fortunately this value is rather constant for all trees, and in a large study in Finland the range in carbon dry mass fraction was found to be 0.515, 0.528, 0.516 and 0.515 for stems, branches, bark and foliage of Norway spruce, respectively (Nurmi 1997). When carbon stock is calculated from total biomass, a value of 0.500 has commonly been applied (cf. Perrin *et al.* 2000, Baritz & Strich 2000). Some countries use a different carbon concentration for wood from Norway spruce. Sweden, for example, uses 0.450 (Löwe *et al.* 2000) and Finland 0.519 (Tomppo 2000). In comparison with the possible error in the other estimates involved with deriving the total aboveground biomass, the errors due to difference in carbon concentration are relatively small. Therefore we are satisfied with using an average fraction of 0.510 when total carbon stocks in Icelandic forests are estimated, irrespective of species (Sigurdsson & Snorrason 2000, Snorrason *et al.* 2002). This value was found by chemical analysis of wood samples collected in Iceland (Snorrason *et al.* 2000).

All the Nordic and Baltic countries have ratified the Kyoto Protocol and are therefore facing demands for documentation and reporting of forest carbon pools and sequestration. Hence, estimation of forest carbon budgets has a high national priority. This work has therefore high practical value, since it contributes to sounder estimates of national carbon pools in forest ecosystems in the Nordic and Baltic countries.

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Appendix 1. Numeric results for basic density (B^d, g/cm^3), biomass expansion factors (BEF), stem volume over bark (Vol, dm^3), stem biomass over bark (SBIO, kg) and total aboveground biomass (TBIO, kg) for the 16 Norway Spruce trees sampled around Iceland (Figure 1). nd stands for “not determined

Tree No.	Bd (wood + bark)			Bd (wood)			BEF	Vol		SBIO			TBIO		
	Bottom	Middle	Top	Bottom	Middle	Top	-	Real	Eq. 1	Real	Eq. 2	Eq. 1, 5	Real	Eq. 4	Eq. 1, 5, 3
1	0.53	0.39	0.33	0.53	0.42	0.38	2.28	1.9	1.6	0.9	0.8	0.6	1.9	1.7	1.2
2	0.44	0.41	0.46	0.44	0.40	0.45	2.14	7.0	7.7	3.0	3.3	3.0	6.5	7.1	5.8
3	0.36	0.43	0.46	0.33	0.41	0.44	2.01	25.8	27.9	11.4	11.2	10.7	22.9	22.3	20.6
4	nd	0.34	0.42	nd	0.34	0.42	2.10	27.3	29.2	12.9	11.8	11.2	27.3	28.8	21.6
5	0.35	nd	0.36	0.34	nd	0.35	2.30	47.4	50.9	17.9	19.8	19.3	41.1	39.9	36.9
6	0.32	0.31	0.44	0.32	0.31	0.44	1.62	48.5	53.3	15.9	20.5	20.1	25.8	37.0	38.6
7	0.30	0.32	0.39	0.29	0.32	0.39	1.84	60.3	67.5	21.7	25.6	25.2	40.1	45.4	48.4
8	0.34	0.32	0.34	0.34	0.32	0.32	1.53	83.5	76.4	29.7	28.4	28.3	45.5	43.2	54.3
9	0.34	0.33	0.38	0.35	0.33	0.38	1.79	98.3	117.8	35.8	43.4	42.2	64.0	77.4	81.0
10	0.34	0.31	0.35	0.34	0.30	0.34	1.74	103.8	90.3	35.5	34.0	33.1	61.9	66.4	63.5
11	0.38	0.39	0.41	0.39	0.39	0.39	1.42	126.7	123.9	55.5	44.7	44.1	79.1	62.4	84.7
12	0.31	0.31	0.37	0.30	0.31	0.36	1.46	138.5	135.3	47.3	49.1	47.7	69.2	79.5	91.6
13	0.29	0.30	0.32	0.28	0.29	0.31	2.77	151.3	135.9	50.7	50.3	47.9	140.5	104.8	91.9
14	0.37	0.34	0.37	0.36	0.34	0.37	1.80	159.9	153.9	56.0	55.9	53.4	100.7	99.3	102.5
15	nd	0.33	nd	nd	0.32	nd	2.04	160.2	150.8	55.9	55. 7	52.5	114.1	118.6	100.7
16	0.29	0.31	0.39	0.29	0.30	0.38	1.81	271.2	271.6	112.4	96.8	84.7	203.4	192.4	162.6
Min	0.29	0.30	0.32	0.28	0.29	0.31	1.42	1.9	1.6	0.9	0.8	0.6	1.9	1.7	1.2
Max	0.53	0.43	0.46	0.53	0.42	0.45	2.77	271	272	112	97	85	203	192	163
Mean	**0.36**	**0.34**	**0.39**	**0.35**	**0.34**	**0.38**	**1.92**	**94.5**	**93.4**	**35.2**	**34.5**	**32.7**	**56.0**	**55.6**	**56.2**
SE	*0.02*	*0.01*	*0.01*	*0.02*	*0.01*	*0.01*	*0.09*	*17.9*	*17.4*	*7.0*	*6.2*	*5.6*	*9.9*	*8.8*	*8.7*