Biomass equations and biomass expansion factors (BEFs) for pine (pinus spp), spruce (picea spp.) and broadleaved dominated stands in Norway.

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Preface

With this Master's thesis, I am finishing my Master's degree at the Norwegian University of Life Sciences (UMB). I have been working at the Norwegian Forest and Landscape Institute for several years, and during the last 6 years I have been responsible for all the field work of the National Forest Inventory (NFI). The work on this Master's thesis have given me the opportunity to learn more about the possible use of NFI data, and the SAS-programming that I have learned during this study will also be useful to me in my job.

I would like to thank my supervisors, Professor Tron Eid at the Norwegian University of Life Sciences, and Research Scientist Rasmus Astrup at the Norwegian Forest and Landscape Institute. They have helped me with in finding relevant literature, answered my questions, and have given me advice about model development. I would also like to thank Research Scientist Gro Hylen for helping me to get started with programming in SAS, and Ph.D. student Aaron Smith for proof-reading, both from the Norwegian Forest and Landscape Institute.

I would also thank the Norwegian Forest and Landscape Institute for giving me the opportunity to work on this Master's thesis as part of my regular job at the institute.

Abstract

The objectives of this study were (1) to develop models for estimation of stand-level tree biomass for spruce *(picea spp.)*- pine *(pinus spp.)*- and broadleaved-dominated forest in Norway and, (2) develop biomass expansion factors (BEFs; ratio of stem volume to biomass) which convert stem volume to whole tree biomass for Norwegian forest conditions. A dataset from a 5 year period (2006 – 2010) from the Norwegian National Forest Inventory (NFI) were used to develop the BEFs and models. For construction of BEFs the whole dataset was used, while for the development of models, the data was divided in two sets. One dataset for model development (80%) and a validation dataset (20%).

Swedish tree-level biomass equations were used for the construction of the models and BEFs since the existing biomass equations in Norway are based only on data from local conditions in parts of the country.

Three tables with BEF-values were constructed. One general table for all areas within “Other wooded land”, “Productive”- and “Non-productive forest”, and two tables for Productive forest in development class III – V. The two tables for productive forest were divided into spruce, pine and broadleaved dominated forest, and showed BEFs varying with site index in combination with age classes or volume classes per hectare. In general, the BEFs decrease as stand age or volume per hectare increases, and the BEFs are lower at high productive sites compared to low productive sites. Since there are rather large differences in BEF ratio between low- and high-productive sites, the inclusion of site index classes in the tables most likely makes the BEFs more applicable in Norway compared to developed BEFs from Finland which frequently have been applied in Norway.

Stand-level models for estimation of biomass from the different tree components; stem, bark, living branches, dead branches, foliage, below-ground for bioenergy use, total below-ground and total biomass were developed. Volume per hectare and site index were chosen as independent variables to be included in the models, and since the relationship between volume and biomass was slightly nonlinear, a nonlinear function was used.

The selected functional form was:

$$\hat{Y} = \beta + \beta_1 \times Volume^{\beta_2} + \beta_3 \times Siteindex$$

Where $\hat{Y}$ is the predicted biomass while $\beta, \beta_1, \beta_2, \beta_3$ are the estimated regression parameters.

In order to account for the heteroskedasticity the models were fit with a normal probability density function (error distribution) where the variance increased proportionally to the predicted value.

The new models have high r^2 values ranging from 0.975 to 0.998 for the components; stem biomass-, total above-ground biomass- and total biomass. Living branches, dead branches and foliage components had lower r^2-values, which varied from 0.575 to 0.962. A t-test based on the validation-dataset comparing the estimates from the new stand-level models to the total biomass calculated from the Swedish equations showed that the new models predict quite similar total biomass estimates for a wide range of stand characteristics such as stand age, volume per hectare and site index. However, the models for stands dominated by coniferous species estimated significantly lower total biomass compared to the Swedish tree-level equations in low-productive stands (site index class 6), on the west-coast, and frequently in the southeast region at elevation higher than 750 meters above sea. In general, at elevation lower than 250 meters in the southeast region, the new coniferous models predicted higher biomass than the estimates from the Swedish equations.

The total biomass and below-ground biomass estimates from the stand level models developed in Finland were in general substantially lower than the estimates from the tree level equations from Sweden, and will most likely result in an underestimation of biomass when applied in Norway.

Key words: biomass, BEFs, models, equations, forest, Norway, spruce, pine, broadleaved

1. Introduction

Given the current focus on climate change and forestry there is a need to obtain reliable estimates of forest biomass. This applies to estimating carbon sequestration as well as potential biomass output from the forest to bioenergy.

The United Nations Framework Convention on Climate Change (UNFCCC) demands estimates on total forest carbon stock and stock changes in the reports according to the Good Practice Guidance for Land Use, Land –Use Change and Forestry (IPCC, 2006) Carbon reporting requires total biomass estimates to quantify carbon storage from five different carbon pools; above- and below-ground biomass, dead wood, litter, and soil organic matter (IPCC 2006).

The Norwegian government wants to increase the use of bioenergy in the country, and forest resources will be an important source for this commitment. (St. meld. nr. 34. 2006-2007). In estimations and analyses of bioenergy from forest, it is important to be able to separate the trees in different fractions so the actual biomass for bioenergy purposes can be calculated (Eid, et al. 2010). The fractions of the trees we need to calculate for this purpose are: stem, stump, roots (excluding fine roots), branches and top.

In cases where individual tree data is available, line in national forest inventories in Scandinavia, biomass is normally estimated with individual tree biomass equations that use diameter and height as input variables (e.g. Braekke 1986). The reporting in the LULUCF-sector to the UNFCCC for Norway is based on the Norwegian National Forest Inventory (NFI) data, and the use of Swedish biomass equations (Marklund 1988; Petersson and Ståhl 2006) to calculate total biomass. Marklund's (1987, 1988) equations are developed from a large and representative sample which covers different forest types, growing conditions, and silvicultural management regimes. The below-ground biomass is calculated using Petersson and Ståhl's (2006) equations because Marklund's (1988) equations for roots only cover the parts of the root system that can be extracted for bioenergy. Marklund's (1988) biomass equations have been used in several biomass calculations in Scandinavia over the last several years (e.g. Hoen and Solberg 1994; Minkkinen et al. 2001).

Biomass equations developed in Norway exists (e.g. Bollandsås et al. 2009; Korsmo 1995; Braekke 1986), but the general problem with most of them is that they are developed from a low number of trees, and only represent local conditions from parts of the country (Eid, et al. 2010). The uncertainties associated with using these equations in Norway are considered to be higher than using Marklund's (1988) equations, even though Norway is outside the geographical area where Marklund's equations are developed. The forest conditions in Norway and Sweden are similar in parts of the respective countries, and since Marklund's equations are based on a large and representative sample from Sweden, they are considered to be applicable in Norway also. The areas where there is likely to be the highest uncertainty in using Swedish equations are in the western and northern parts of the country where the forest conditions are quite different compared to any region in Sweden. A research project at the Norwegian institute of Forest and landscape is currently developing Norwegian biomass equations for birch ("Biomass allocation of individual birch trees along an environmental gradient", Smith and Granhus - in progress), but there are no current plans to do the same for pine and spruce.

In Finland several tree level biomass equations for the most common tree species have been developed (e.g. Simola 1977; Hakkila 1979; Korhonen and Maltamo 1990). Repola (2008, 2009) developed biomass equations for spruce, pine, and birch based on sampled material from several hundred trees. Repola's data material was collected from sites covering most parts of the country, but mainly on mineral soil.

In cases where individual tree data is not available, biomass is normally estimated with biomass expansion factors (BEFs) that use estimated timber volume in combination with other stand-level variables to estimate plot-level biomass (e.g. Tobin and Nieuwenhuis 2007). Examples where individual tree data is not available is forest estate inventories and plans, and forest scenario models with stand-level growth functions such as Avvirk -2000 (Eid and Hobbelstad 2000) and Gaya (Hoen & Gobakken 1997).

A biomass expansion factor can be a constant (e.g. Sharp et al. 1975; Turner et al. 1995), but because BEFs may vary with tree age and stand conditions (Petersson et al. 2012), the estimates will probably be improved by applying age-dependent BEFs (Lethonen et al. 2004) or other stand characteristic such as volume as explanatory variables (e.g. Brown & Lugo 1992; Schroeder et al. 1997; Fang et al. 1998).

A biomass expansion factor for Sitka spruce (Sitka sitchensis) in Norway was developed in a master thesis by Johnsen (2009). Today, there are no other Norwegian biomass expansion factors. Finish biomass expansion factors developed by Lethonen (2004) have been used in several Norwegian studies (e.g. de Wit et al. 2006). However, the Finnish biomass expansion factors were developed by applying individual tree biomass equations from Sweden (Marklund 1988) to the Finnish NFI data. As Finish forest conditions and Norwegian forest conditions may be different, the Finnish biomass expansion factors are potentially not suitable for use in Norway.

1.1 Objectives

The main objective of this study is to develop models (equations) and BEFs for stand-level biomass estimation for Norwegian forest conditions that may be used for bioenergy as well as carbon accounting purposes. The models should be tree species-specific (spruce, pine, and broadleaves) and cover both above- and below-ground tree components for productive forest. The models should be based on variables that are normally measured in forest inventories or that easily can be estimated from inventory data. Furthermore, this study has two additional objectives:

(1) Compare different biomass equations from Finland and Sweden in order to select the equations to be used in the construction of the models.
(2) Compare the developed models with existing fennoscandic biomass expansion factors and equations.

2. Material and methods

2.1 Data

Tree and stand variables collected in the period 2006 to 2010 from the Norwegian National Forest Inventory (NFI) was used for this study. Permanent sample plots were established in a 3 x 3 km grid below the defined coniferous forest limit in the period 1986 – 1993 in all counties except Finnmark. Beginning in 1994, 20% of the permanent plots have been inventoried each year. This continuous inventory makes it possible to produce information about forest resources in Norway each year based on the last 5 year period. (Tomter et al. 2010). In 2005, the NFI received funding to include the mountain birch areas and permanent plots were established on a 3 x 9 km grid in mountain birch areas located over the previously defined coniferous forest limit. Permanent plots have also been established in Finnmark County over the last 7 years (Landsskogtakseringens feltinstruks, 2011), but the data handling will not be finished before the summer of 2012. The plots from Finnmark are therefore not included in the data material used in this study.

The Norwegian NFI covers forest of all ownership groups, also including protected forest and other land-use classes. Total amount of plots registered in all counties except Finnmark in this 5 year period are 21281, of which, 13409 of them were visited and assessed in the field (Table 1). Approximately 11.500 of those plots are defined as forest.

***Table 1**. Land cover and Land use classes on plots visited in the field 2006 – 2010 (For divided plots only part 1 are counted)*

Land cover	Land Use Forestry (no other use or re-strictions)	Protected area, Recreation area	Cabin area, Military training field	Powerline	Other	TOTAL
Productive Forest[1]	8868	181	23	25	3	9100
Non-productive Forest[2] [3]	2334	110	10	5	0	2459
Other Wooded Land[4]	746	46	4	0	0	796
Other areas (grazing land, mire without tree cover, bare rocks, forest roads etc)	671	42	2	1	1	717
TOTAL	12637	380	41	31	320	13409

Only plots defined as Forest or Other Wooded Land within land use classes Forestry area, Protected area or Recreation area were included in the calculations of biomass expansions factors. Plots located in the Cabin area, Military training field, and Powerlines land use classes were excluded. For the development of models, only Productive Forest plots within land use Forestry and Protected area or Recreation area in development class III – V were used. In forest plans for forest owners and other data from forest areas, development classes I and II are often without information about volume per hectare or the volumes are only provided for scattered bigger trees (standards).

For all permanent plots included in the model data, all trees with a diameter at breast height with bark (dbh) > 5 cm inside a circular plot of 250 m^2 (radius 8.92 m) are assessed. Tree species, diameter at breast height, condition of the tree, and direction and distance from the center of the plot are recorded. Sample trees are selected by relascope using an adjustable basal area factor that aims for selecting 10 sample trees on each plot. Tree species, dbh and height are measured for these trees. Based on sample trees, heights for all trees inside the 250 m^2 are calculated. If there are boundaries between stands or different land-use classes that cross inside the 250 m^2 plot and the smallest part covers at least 15% of this area, the plot should be divided in to parts with their own separate registrations. (Landsskogtakseringens feltinstruks, 2011)

[1] Productive forest: Land with tree crown cover > 10%, minimum productivity of 1 m^3/ha/year (incl. bark).
[2] Non-productive forest: Land with tree crown cover > 10%, productivity of < 1 m^3/ha/year (incl. bark).
[3] The trees should be able to reach heights of 5 meters. Forest land can also be temporarily unstocked as a result of human intervention or natural causes, but are expected to revert to forest.
[4] Other Wooded Land: Land with tree crown cover of 5-10%, or > 10% crown cover including trees not able to reach a height of 5 meters

Stand descriptions such as land-use class, crown cover, stand age, site index, dominant tree species, and development class are assessed on a circular sample plot with a radius of 17.84 m (1000 m^2). When there are different stands, another land cover class or land-use classes inside this circle, the radius of the circle is expanded until the area(s) of the stand(s) being described are 1000 m^2. (Landsskogtakseringens feltinstruks 2011).

2.2 Volume and biomass equations

The stem volume in the Norwegian NFI tree and plot database is calculated from individual tree volume equations (Brantseg 1967; Vestjordet 1967; Braastad 1966) for Norway spruce *(Picea abies)*, Scots pine *(Pinus silvestris)* and Birch *(Betula pubescens and Betula pendula).* These equations are also used to calculate volume for all other species like for example Elm *(Ulmus Glabra)* or Larch *(Larix spp.,)* except for Sitka spruce *(Picea sitchensis)* where the equations from Bauger (1995) are used. In the western parts of the country the equations from Bauger (1995) for Norway spruce, Scots pine and Sitka spruce are used for all the coniferous tree species.

If the tree has a stem break with diameter > 10 cm at the breaking point, the predicted volume of the tree in the NFI database is reduced by a reduction factor. The factor is determind by the forest surveyor in the field by using tables where input variables are tree height and height to the break (Landsskogtakseringens feltinstruks 2011).

The Swedish equations from Marklund (1988), Petersson and Ståhl (2006), and the Finnish equations from Repola (2008, 2009) were used to calculate biomass of each component of a tree in the present study. Marklund's (1988) equations provide biomass estimates for Scots pine and Norway Spruce for the components; stem, stem bark, living branches, dead branches, needles, stump, roots greater than 5 cm in diameter, and roots less than 5 cm in diameter. According to Marklund (1988), the equations for roots > 5 cm should not be applied to trees with a diameter at breast height of less than 10 cm because such large roots have not yet formed on trees of this size. Roots > 5 cm are therefore only calculated for trees with a diameter of 10 cm or more. The equations for belowground biomass from Marklund (1987, 1988) were developed to predict the biomass of roots obtained in operational root extraction for bioenergy. For birch, Marklund only constructed equations for above-ground biomass for the stem, stem bark, and living and dead branches excluding foliage. In the NFI database, foliage biomass for broadleaved species is estimated using a constant factor multiplied by the stem volume for the actual tree. The factor is 2.2% and was also used in present study (Liski et.al. 2002).

Petersson's and Ståhl's (2006) equations for roots down to 5 mm and roots down to 2 mm were applied for all species, and they include more of the root system than the equations from Marklund (1988). Petersson's & Ståhl's equations also include fine root biomass that cannot be extracted for bioenergy. In order to develop models for below-ground components for bioenergy use for broadleaved species, a correction factor to the calculated belowground birch biomass by Petersson and Ståhl (2006) equations was estimated. The correction factor used was 0.87 (13% reduction) and was determined as the difference between belowground predictions from Marklund's (1988) and Petersson and Ståhls (2006) equations for spruce and pine.

The biomass for all the components (stem wood, stem bark, living branches, dead branches, needles or foliage, stump and roots down to 10 mm, and total above-ground biomass) were also estimated by using equations from Finland (Repola 2008, 2009). The equations for above-ground components were based on a relatively large sample except for the foliage for birch which was based on only 21 sample trees with a diameter range from 11 to 26 cm. The below-ground biomass equations for birch were also based on a very limited sample. Only 6 sample trees had measurements of roots > 10 mm, and these were used to estimate biomass of roots by regression for the rest of the trees in that study.

Trees with stem breaks > 10 cm had their calculated above-ground components reduced with the same factor as that used to reduce the stem volume in the NFI database. This will most likely lead to an underestimate of the actual biomass due to the fact that the distribution of branches and foliage biomass compared to stem biomass are different in the top of a tree compared to lower parts. The top of for example a 20 meter high spruce tree obviously in most cases will have more needles and living branches compared to the stem than the lower parts of the tree. Equations that calculate biomass specifically for the different tree components of the upper part of the tree do not exist, so this reduction of biomass is only an approximation. This reduction factor method is also used in the NFI database on below-ground components. Trees with small or relatively new stem breaks will probably have almost the same below-ground biomass immediately following the break, but for trees that have had a large part of the stem and crown missing for several years will maybe have a different pattern of root development compared to a tree without a stem break. Vanninen and Makela (1999) found that fine root biomass of Scots pine was proportional to foliage biomass, but could not see the same trend for large roots. In this study the calculated biomass for stump and roots were not reduced on trees with stem breaks.

The calculated biomass for each component, the sum for above- and below-ground biomass, and the total biomass for each main species were compared by using different equations.

2.3 Construction of BEFs.

Simple BEFs in tables that convert stem volume to dry weight of total biomass were developed by using the tree dataset from the NFI from the period 2006 – 2010.
The BEF-tables were calculated with equations from Sweden using Marklund’s (1988) above-ground equations and Peterson and Ståhl’s (2006) equations for below-ground biomass including roots down to 2 mm. BEF-tables based on the Finnish equations from Repola (2008, 2009) were also made for comparison (Appendix, Tables A1, A2).

Expansion factors from stem volume to dry weight were calculated following the same procedure as the Finnish BEFs (Lethonen et. al. 2004). The BEF, B_i for the different land cover types “Other Wooded Land”, “Non Productive-“ and “Productive Forest” were calculated by dividing the sum of the biomass (W_i) for component *i* (foliage, living branches, dead branches, bark, stem, stump, roots or whole tree) for all trees in all sample plots belonging to the land type class by the total stem volume (V) for the same plots.

$B_i = W_i / V$

The total sum was weighted by the area of each plot or part of a plot represents in order to get country representative results. A plot in the mountain area with a grid of 3 x 9 km represents 27 km^2 while a plot at the 3 x 3 grid represent 9 km^2. A partial plot (plots divided between stand boundaries, land cover types or land use classes) is given a weight according to the size of the divided part. For example a 40% part of a plot represent an area that is 40% of a full plot, and is given a 40% weight of a full plot in the grid.

The same procedures were used to obtain BEFs for different age classes and classes of volume per hectare.

Dominant tree species for each plot were determined from volume per hectare for each main species (spruce, pine and broadleaves) based on the tree measurements inside the 250 m^2 area, and not the parameter "stand species" estimated in the field in the stand description area of 1000 m^2. For most of the plots the results regarding dominant species will be the same, but 13% of the plots come out with different results. The site index is given for the dominant main tree species calculated of the distribution from the parameter "stand species". This could lead to errors if site index class is not the same for different species at the same plot. A plot with an estimated stand species distribution of 55% pine and 45% spruce could be spruce-dominated when the volume from the trees inside the plot directly decides the distribution and thus the main species. In this example the plot will come out as spruce-dominated, but the site index is given from pine. This is obviously a source of error, but the advantages of using the distribution directly from the calculated volume per hectare, is that it is a measured value and not based on subjective assessments.

2.4 Model development.

For model development, the dataset from 2006 – 2010 was divided into two new datasets in order to have a model development data and a validation dataset. The dataset for construction of the models had 80% of the plots randomly selected, while the other validation dataset comprised of 20% of the plots.

In order to identify promising independent variables for the stand-level models, Pearson correlation coefficient analysis was carried out for the biomass and selected stand variables in the NFI dataset (see Table 2). The total biomass per hectare used in this computing was calculated using the equations from Marklund (1988) for above-ground and Petersson and Ståhl (2006) for below-ground biomass.

Table 2. *Pearson correlation coefficient r for biomass per hectare and different stand variables (Productive forest in development class III – V)*

	Bio-mass/ hectare	Mean diam	Basal area	Site index	Vol/ hectare	Stand Age	Mean height	Trees per hectare	Elev-ation above sea l.	Alti-tude slope
Biomass /hectare	1	0.421	0.973	0.551	0.977	0.014	0.700	0.330	-0.155	0.061
Mean diameter	0.421	1	0.385	0.023	0.452	0.585	0.697	-0.456	0.047	0.042
Basal area	0.974	0.385	1	0.506	0.945	0.005	0.623	0.423	-0.157	0.065
Site index	0.551	0.023	0.506	1	0.554	-0.530	0.473	0.321	-0.343	-0.025
Vol/hectare	0.977	0.452	0.945	0.554	1	0.033	0.753	0.263	-0.159	0.015
Stand Age	0.014	0.585	0.005	-0.530	0.035	1	0.254	-0.437	0.246	0.023
Mean height	0.700	0.697	0.623	0.473	0.753	0.254	1	-0.096	-0.109	-0.045
Trees per hectare	0,330	-0,456	0,423	0,321	0,263	-0,437	-0,096	1	-0,141	0,045
Elevat.ab,sea lev.	-0.155	0.047	-0.158	-0.343	-0.159	0.246	-0.109	-0.141	1	-0.118
Altitude slope	0.061	0.042	0.065	-0.025	0.015	0.023	-0.045	0.045	-0.118	1

The correlation analysis illustrated that biomass per hectare is strongly correlated with basal area and volume per hectare. Other variables with relatively high correlation are mean height ($r = 0.700$) and site index ($r = 0.551$) while stand age showed hardly any correlation at all ($r = 0.014$). Basal area and volume per hectare are highly correlated ($r = 0.945$) and simultaneous use of both as explanatory variables would lead to multicollinearity.

In the early stages of this analysis, several preliminary simple linear regressions models with different combinations of the parameters listed in table 2 were tested. The results showed that basal area and volume used as independent variables in the models gave nearly the same r^2 values, but that volume were slightly better than basal area. At the same time, in forest plans and estate level inventories, volume per hectare is almost always present making volume a preferable variable compared to basal area. Hence, it was decided to include volume in the models and exclude basal area. The preliminary regression analysis also showed that site index as an independent variable in addition to volume per hectare would improve the models in most cases. On the other hand, "mean height" was found to be too strongly correlated with volume per hectare to be included in the models.

The preliminary linear regression analysis illustrated two additional important points: (1) the residuals showed a clear heteroskedastisity (such as often observed for biomass data (Parresol 1999)) and (2) the relationship between volume and biomass was slightly nonlinear. In order to account for the nonlinearity it was decided to fit a nonlinear function to the data. The selected functional form was:

$$\hat{Y} = \beta + \beta_1 \times \text{Volume}^{\beta_2} + \beta_3 \times \text{Siteindex}$$

Where $\hat{Y}$ is the predicted biomass while $\beta, \beta_1, \beta_2, \beta_3$ are the estimated regression parameters and Volume and Siteindex are the independent variables.

In order to account for the heteroskedasticity we followed the example of Lilles and Astrup (2012) and fitted the models with a normal probability density function (error distribution) where the variance increased proportionally to the predicted value. Hence, the error (ε_i) for the *i*th observation was modeled as

$$\varepsilon_i = \varepsilon_1 \times X_i$$

where Xi is the predicted value and ε_1 is a parameter estimated with maximum likelihood simultaneously with all the parameters from the functional form.

In practice the models were fitted with the Proc NLMIXED procedure in SAS. In order to ensure the global optimum was reached several search algorithms and initial start values were tested for each model.

The model was fitted for forest with mixed species and 3 species –specific models were developed for pure stands. Pure stands were defined as forest where more than 70% of the volume consists of one of the main species; spruce, pine and broadleaves. In the NFI database all the broadleaved species have their volume calculated by use of equations for birch (Braastad 1966), and the estimation of biomass for each tree in the present study are based on Marklund’s (1988) and Peterson and Ståhl’s (2006) equations for birch. Hence, it was decided not to separate broadleaved forest into stands like birch-, alder-, or aspen-dominated.

In order to evaluate the developed models paired t-test were run based on the validation data (20% dataset) to compare the estimated biomass from the developed stand- level models and the estimated biomass based on biomass equations (Marklund 1988; Petersson and Ståhl 2006) for components of individual trees. The same was done for the stand-level equations developed in Finland (Lethonen et al. 2004). The t-test computes a mean and standard error of the difference and determines the probability that the absolute value of the mean difference is greater than zero by chance alone. The paired t-test was done for different groups of the material such as main species, site index, age classes, volume classes and regions to explore how good the models are at predicting biomass.

The regions were defined as Southern-, Middle-, Northern-, and Western parts of Norway, where region “South” consists of the counties Østfold, Akershus, Oslo, Hedmark, Oppland, Buskerud, Vestfold, Telemark, Aust- og Vest-Agder. The counties Rogaland, Hordaland, Sogn & fjordane and Møre & Romsdal defines region “West”, while Sør- and Nord-Trøndelag are the “Mid-” parts of Norway. Nordland and Troms is region “North”. The region “South” covers a big area and the plots here were also divided in groups defined by elevation above sea level.

3. Results and discussion

3.1 Comparison of biomass estimation for tree components calculated by Swedish and Finnish equations.

The predictions of different biomass components given by the different models (Figs. 1a – 1d) gave quite similar results for trees with diameter under 25 cm, with the exception of below-ground biomass for birch where Repolas (2009) equations in average gave 37% lower values compared with Petersson's (2006) equation. Here roots down to 0.5 cm are included (Fig. 1c). The difference in estimated below ground biomass increased for broadleaved trees with diameter > 25 cm to diameters around 45 cm where the difference in calculated biomass is large. For dbh 42 cm – 48 cm the equations for birch with roots larger than 2 mm from Petersson and Ståhl (2006) predict more than the double below-ground biomass compared to Repola's (2009) equations who estimates root biomass down to a diameter of 1 cm.

The below-ground equations for pine and spruce from Marklund (1988) is not directly comparable to Repola (2008, 2009) and Peterson and Ståhl (2006) because they cover only roots that can be extracted for bioenergy purposes. For pine the prediction of below-ground biomass from Marklund (1988) gave almost the same results as the other equations, while the predictions for spruce were very similar to the results from Repola's (2008) equations for diameters up to around 40 cm (Fig. 1c.). For larger diameters the predictions of biomass based on Marklund's (1988) equations were substantially lower. Petersson and Ståhl's (2006) equations for below-ground biomass for spruce gave higher biomass than both Repola (2008) and Marklund (1988).

Most of the biomass equations from Repola and Marklund are based on tree diameter and height, and the biggest variation within in diameter (deviations from a straight line in the graphs, see Fig. 1) are due to trees with extreme diameter – height relationship. These trees often give predictions of biomass that are relatively far away from the average for the same diameter.

Some of the trees with an extreme diameter – height relationship are definitely outside the range from where both the volume- and biomass equations are developed. One could suspect that some of the trees have values that are not correct, so they should be considered to be excluded from the material in this study. There could for example be errors caused by data entry mistakes on the field computer. Such an exclusion of single trees was not done because several tests of the data are run when the data are received in the NFI database. Trees with extreme values or development from the last inventory that clearly is not logical will be listed and the field worker will get an e-mail where he should explain the values. Trees with small negative differences in diameter from the previous inventory are not listed. In addition to this, several other tests on the tree data are run after the field season is finished (Tomter et al. 2010). This means that all the errors that you could expect to find and correct have already been corrected. Extreme values could also be variations that occur in the forest, and it would be difficult to separate errors from real values. Where diameter is the only variable such as in the equations from Petersson and Ståhl (2006) for below ground biomass (Fig. 1c), the predicted values will not give these variations in estimated biomass.

For trees with diameter > 25 cm the models from Repola (2009) predicted substantially lower stem biomass than Marklund's (1988) models for spruce and pine, while the equations for stem biomass of birch gave estimates that were similar (Appendix, Figs. A1 – A3). The biomass in the crown including living and dead branches as well as needles gave quite similar predictions for pine and spruce, while the results for birch gave different results (Fig. 1b). The birch model from Repola (2008) predicts higher values of crown biomass for diameters > 25 cm compared to Marklund, and the difference is increasing with larger trees. The foliage biomass for broadleaved species included in the crown estimates from Marklund (1988) is calculated by use of the factor from Liski et. al. (2002).

When the total sum of the different biomass parts for each tree is calculated, Repola's (2008, 2009) equations yield similar predictions for spruce, pine and birch compared to the Swedish equations (Marklund 1988; Peterson and Ståhl 2006) when diameter is < 25 cm for the conifer species and < 20 cm for birch. When the diameter increases Repola's equations predict substantially lower total biomass for all species (Fig. 1d). The maximum diameter in Repola's data material was 35 cm for pine, 42 cm for spruce and 38 cm for birch, while Marklund's equations for pine, spruce and birch goes up to 45, 50 and 35 cm respectively.

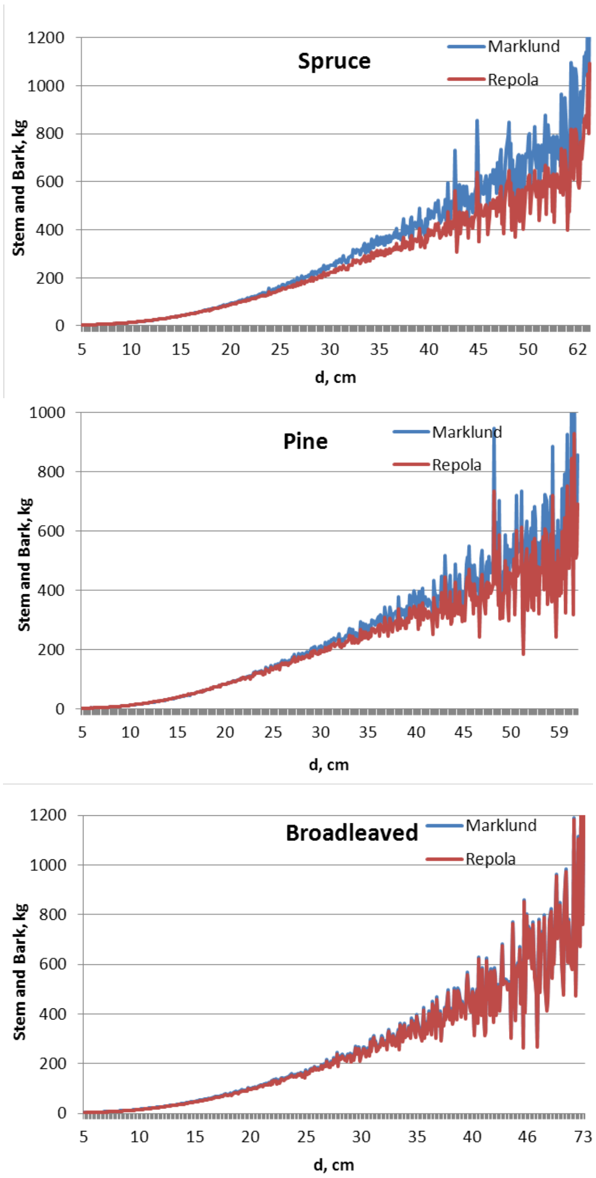


Figure 1a. Calculated stem and bark biomass in the NFI data using equations from Marklund and Repola. (spruce-, pine- and broadleaved-dominated forest)

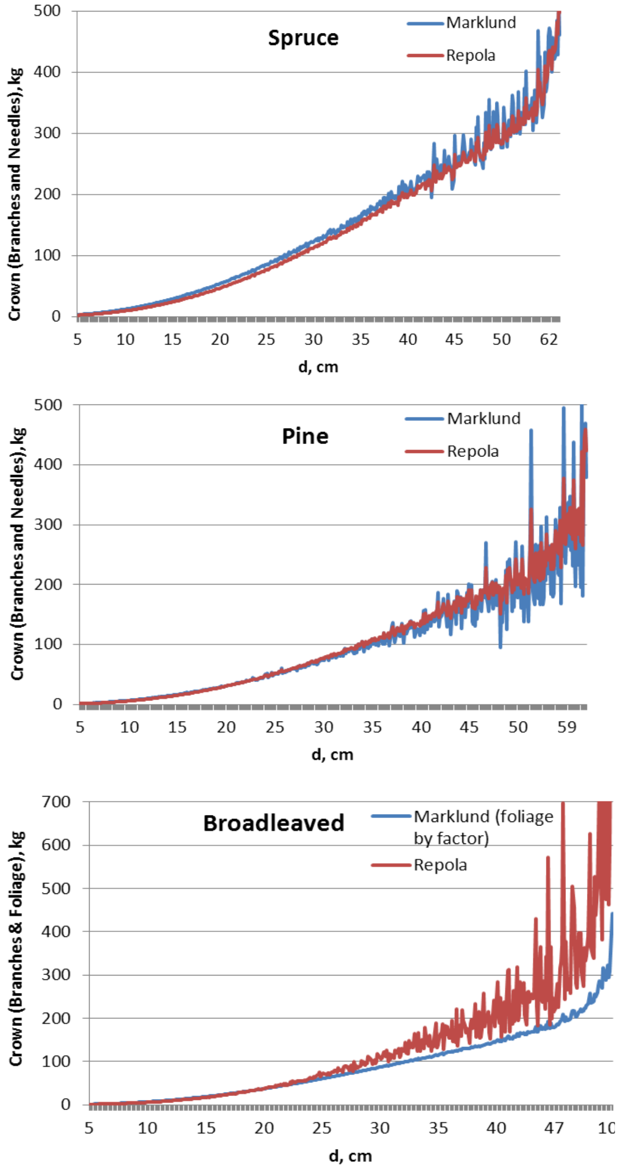
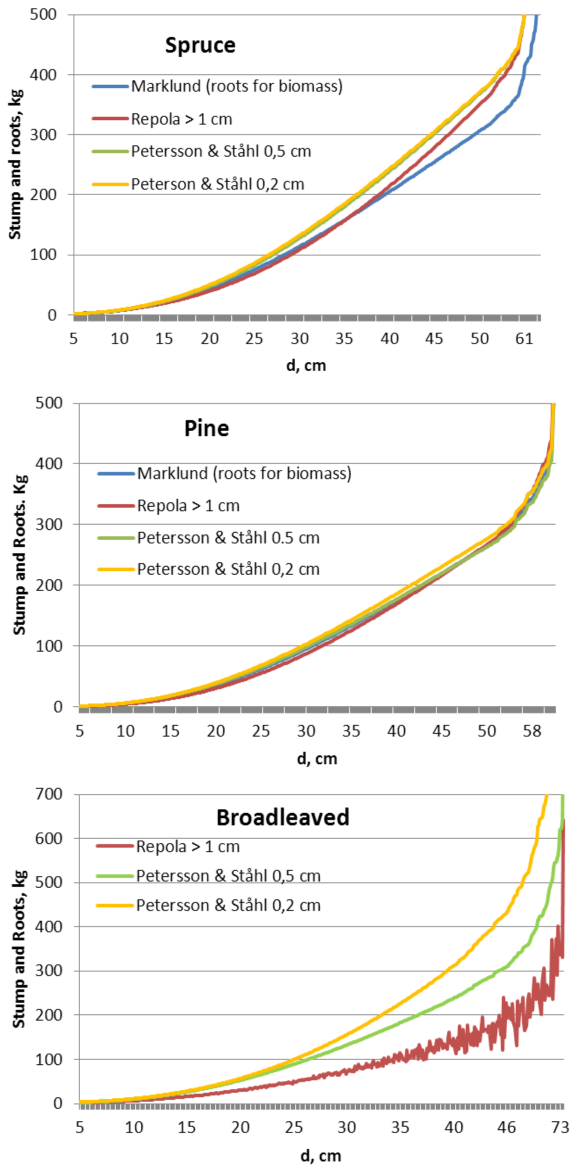


Figure 1b. Calculated crown biomass in the NFI data using equations from Marklund and Repola. Foliage of broadleaved species (Marklund) estimated by using a constant factor of 2,2% multiplied by the stem volume for the actual tree.



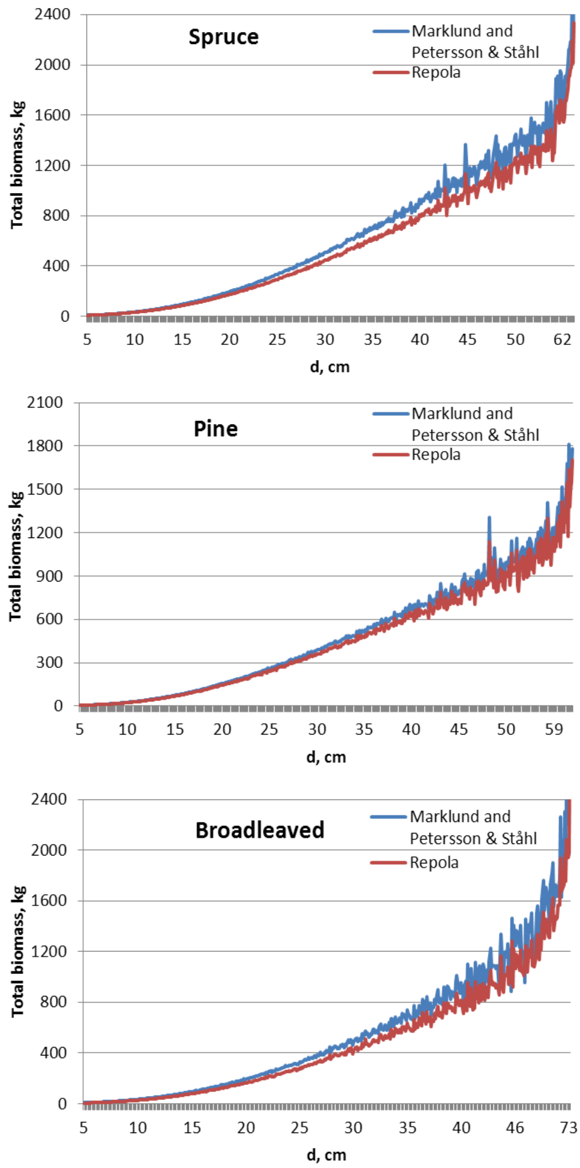


Figure 1c. Calculated below-ground biomass in the NFI data using equations from Peterson & Ståhl and Repola (spruce-, pine- and broadleaved-dominated forest)

Figure 1d. Calculated total biomass in the NFI data using equations from Peterson & Ståhl and Repola. Foliage in Marklund for broadleaved species estimated by using a constant factor multiplied by the stem.

Large differences in calculated biomass and thus BEFs were observed in non- productive forest, other wooded land and low productive forest with site index 6 – 8 (Table 3 and 4, Appendix table A1 and A2), and this could partly be caused by the fact that the equations were used outside their validity range. The stands chosen for development of equations for birch in Finland by Repola (2008) were only taken from sites with moderate to high productivity, so stands with low site index were not represented. The Finnish biomass equations for all the main tree species (pine, spruce and birch) cannot be described as country representative because the stands were subjectively selected and most of them were located in the southern parts of Finland and mainly on mineral soil sites. A clear disadvantage of using Repola’s (2008, 2009) equations in developing models or BEFs for forest in Norway is that the entire data material from Finland are based on even-aged forest, while in Norway 28 and 21% of the productive forest area in development class IV and V is defined as multi-storied (Larsson & Hylen 2005). Repola (2009) states that “in the northernmost parts of Finland, in coastal areas and on peatlands, the validity of the equations is uncertain” due to lack of data.

Marklunds (1987, 1988) data material is described as country representative and is commonly used in the Scandinavian countries (e.g. Petersson et al. 2012; Liski & Westman 1995). According to Karkkainen (2005), Marklund’s equations can also be used for trees growing on peat lands. Large forest areas in the west and north of Norway are quite different from Swedish forest conditions, and to use his equations here are definitely outside the range from where the data is developed. Compared to Repola’s (2008, 2009) data however, Marklund’s data material covers more forest types and silvicultural treatments and in addition the equations are valid for larger trees. All this favors selecting Marklund equations instead of Repola’s for construction of the models.

Several biomass equations exist in Norway but none of them are developed from data materials that could be described as country representative. One solution to this problem could be to use Marklund’s (1988) equations and develop models that convert volume to biomass for stand-level data in areas considered to be similar to the forest conditions in Sweden. Areas or forest types where Norwegian biomass equations exist could be used to develop stand-level models for those forest types. An example is the biomass models for birch at high altitudes in Norway made by Bollandsås et al. (2009). These models are most likely better in predicting biomass for birch forest in the mountains than equations from other countries. This procedure was not chosen, however, and one of the reasons was that the idea behind this study was to develop one set of models that could be used for the whole country.

Based on these on the above discussed issues, Marklunds equations are considered to be the best alternative when models should be developed for Norway. Models based on Repola will estimate significant total lower biomass compared to models based on the Swedish equations (Fig. 1d, Appendix, Tables A1, A2).

3.2 BEFs for Other Wooded Land, Non Productive Forest and Productive Forest.

The land cover types showed a big difference in the calculation of stand-level BEFs using different equations from Sweden and Finland (Table 3). For all main species and both Productive, Non-Productive and Other Wooded Land Repola's (2008, 2009) equations gave substantially lower BEFs than the combination of equations from Marklund (1988) and Petersson and Ståhl (2006).

Comparing the main tree species, pine-dominated forest gave the lowest BEF-values in Productive and Non-Productive forest. The highest BEF-values were obtained in areas defined as "Other Wooded Land" for all main tree species, while Productive forest had the lowest BEFs.

Table 3. Simple BEFs (Mg m^{-3})[5] for forest- and other wooded land.

Equations from:	Produktive Forest			Non-Productive Forest			Other Wooded Land		
	Spruce	Pine	Broad-leaved	Spruce	Pine	Broad-leaved	Spruce	Pine	Broad-leaved
Marklund and Peterson & Ståhl	0.836	0.741	0.992	1.141	0.970	1.055	1.305	1.073	1.071
Repola	0.737	0.676	0.829	0.986	0.807	0.861	1.107	0.850	0.873

BEFs developed in Finland have lower values than the results in this study. The overall values of BEFs developed by Lethonen et al. (2004) were 0.7051 Mg m^{-3} for Scots pine stands and 0.8139 Mg m^{-3} for Norway spruce stands with tree volume production of more than 1 m^3 ha^{-1} per year. Constant BEFs applied for carbon stock assessments in Finland are even lower; 0.716 Mg m^{-3} for Norway spruce and 0.595 Mg m^{-3} for Scots pine (Tomppo 2000).

The BEFs for total biomass over age classes for the according to different dominant tree species are shown in Table 4. The BEFs of spruce-dominated stands in general decreased as stand age increased. This pattern could be seen for all the site index groups from the age classes 20 – 29 to 70 – 79 years. All main species had higher BEF values at age class 10-19 compared to age class 1-9 with the exception of high productive broadleaved forest. At age class 1-9 a lot of the volume is calculated from standards since most of the young trees in the stand are too small to be measured.

[5] Mg m^{-3}= Dry weight in megagram (10^6) – tons (1000 kg) per m^3

Table 4. BEFs (Mg m^{-3}) by stand age classes and site index (from Marklund and Petersson & Ståhl).

Age class	Productive Forest								
	Spruce-dominated			Pine-dominated			Broadleaved dominated		
	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →
1-9	0.970	0.970	0.896	0.798	0.689	0.650	1.022	0.985	1.001
10-19	1.113	0.988	0.999	0.835	0.734	0.761	1.073	1.022	0.986
20-29	1.070	0.998	0.941	0.848	0.777	0.780	1.038	1.011	0.950
30-39	1.072	0.960	0.871	0.834	0.778	0.719	1.029	0.990	0.934
40-49	1.048	0.915	0.797	0.875	0.770	0.693	1.031	0.983	0.903
50-59	1.043	0.875	0.765	0.850	0.727	0.675	1.040	0.982	0.901
60-69	1.010	0.845	0.747	0.873	0.725	0.662	1.026	0.983	0.914
70-79	1.008	0.837	0.749	0.862	0.736	0.639 (*)	1.033	0.988	0.915
80-89	1.039	0.816	0.739	0.837	0.719	-------	1.031	0.997	0.927
90-99	0.993	0.828	0.711	0.848	0.733	0.743	1.034	0.995	0.934
100-109	0.989	0.801	0.719	0.812	0.708	0.663	1.045	0.981	0.871 (*)
110-119	0.944	0.814	0.706	0.790	0.697	0.643 (*)	1.046	0.952	0.958 (*)
120-129	0.969	0.804	0.701	0.772	0.681	0.664 (*)	1.018	0.921	-------
130-139	0.942	0.778	0.743 (*)	0.768	0.689	-------	1.035	0.993	-------
140-149	0.953	0.797	-------	0.778	0.672	-------	1.019	1.000	1.018 (*)
> 150	0.931	0.801	0.714 (*)	0.760	0.675	0.599 (*)	1.008	0.773 (*)	-------

(*) < 5 plots as basis for the calculation of BEF

The BEFs estimated for broadleaved-dominated forest generally did not vary much over different age classes (Table 4). Larger variation in BEFs for pine in site index class ”17→” and birch in site index classes “11-14” and “17→” occurred at old stand ages although these BEFs are probably imprecise because of few observations in these age classes. Both spruce- pine- and broadleaved-dominated stands gave lower BEFs when the productivity in terms of site index increased. For the coniferous stands, the difference between low site index and medium site index were rather high, e.g. spruce-dominated stand with stand ages around 50 – 100 years old had approximately 15 – 20% lower BEF values at site index “11 – 14” compared to site index “6 – 8”.

BEF-values from the Finnish equations followed the same trend as the Swedish, and the main difference between the results were that Repola’s (2008, 2009) equations predicted lower BEFs at all stand ages and site indices (see Appendix, Table A1). In general the differences in BEFs between the site index classes were larger for BEFs based on the Swedish equations compared to Repolas.

The age dependent BEFs developed in Finland (Lethonen et al. 2004) were based on 3000 permanent sample plots from the Finnish National Forest Inventory in 1985 – 1986, and Marklund’s (1988) equations from Sweden were used to estimate biomass. Marklund’s equations predicts less below-ground biomass (15% lower on average for spruce and 9% lower for pine) than Petersson and Ståhl (2006), so it would be expected that the BEFs developed in this study will have higher values than the Finnish BEFs. Calculation of total biomass based on all the single trees in the Norwegian NFI database will give near 4% and 2% lower biomass estimates when Marklund's equations are used compared to Petersson and Ståhl's equations for roots down to 2 mm, for spruce and pine respectively.

The ratio of tree volume to tree biomass is not constant over tree age, and the stem proportion normally increases with tree size, while the branches, foliage, stump and roots proportion are decreasing (Petersson et al. 2012). The Finnish BEFs from Lethonen et. al. (2004) for Scots pine were very similar for all the different stand age classes, the lowest BEF-value was 0.690 Mg m^{-3} in age class "140 →" and the highest 0.710 Mg m^{-3} (age class 60 - 69) showing a trend of slightly decreasing as stand age increases. The new BEFs developed for pine-dominated forest in this study in general differ more at different age classes, and have rather large BEF-values for young stand ages (20 – 50 years). Spruce-dominated forest follows the same pattern as pine-dominated, but the differences between age classes are larger, and this was also the results in the study from Lethonen et. al. (2004). Kauppi et al. (1995) also found that BEFs for Norway spruce stands decrease with higher stand age, but their calculations of BEFs were substantially lower than the result here.

The Finnish age dependent BEFs (Lethonen et al. 2004) do not take into consideration site index, but the results in this study show big differences in calculated BEFs for different site index classes. Obviously trees growing on low productive sites will have other stem forms (diameter – height relationship) than trees growing on fertile sites with high productivity. By adding site index as a variable in the tables, it clearly increases the applicability of the BEFs. Much more accurate results can be expected particularly when used for forest with low or high site index classes since the calculated BEFs here are very different. If a constant BEF is applied across all site index classes, even though the BEFs are divided into age classes or volume classes, the forest biomass of forest with low productivity is underestimated, while the biomass of high productivity is overestimated.

The BEFs developed for pine-dominated forest with site index class "11-14" gave slightly higher BEFs for stand ages between 50 and 110 years when compared to the Finnish age dependent factors (Lethonen et. al. 2004). Stand ages between 20 – 50 years gave quite large differences e.g. 0.778 Mg m^{-3} in the newly developed BEFs versus 0.710 Mg m^{-3} calculated from the Finnish factors in age class 30 - 39. Low (6 – 8) site index class gave substantially higher BEF values at all age classes e.g. 0.875 Mg m^{-3} in age class 40 – 49 while the BEF developed in the same age class in the Finnish study was 0.702 Mg m^{-3}. Site index class 17 and higher varied more with higher calculated BEFs at stand ages from 10 – 39, and mostly lower values for older stands.

Spruce-dominated forest with site index class "11 – 14" gave quite similar results for stand ages of more than 100 years. The difference for lower ages and site index class "6 – 8" and "17→" followed the same pattern as for pine-dominated forest, but here the difference between the new BEFs and the Finnish BEFs were even larger. For example, age class 10-19 in a spruce-dominated forest has a BEF value of 1.113 when the site index class is "6 – 8", while the BEF value from the Finnish study for stands at the same age is 0.862. At stand age class 120-129 and site index 17 or higher, the computed BEF is 0.701 while the Finnish BEFs were 0.782 for stand ages 120 – 139.

The BEFs of broadleaved stands shows little variation between different stand ages, and the differences from site index 6-8 to more productive site index classes are also smaller than the ones obtained in the coniferous stands.

BEFs were also developed where volume per hectare in combination with site index is used instead of stand age classes (Table 5, Appendix, Table A2). In general, when volume per hectare increases the calculated BEFs decrease. This is clear for the coniferous forest for all site index classes. The BEFs for broadleaved forest also has this trend for site index classes of 11 or higher when volume per hectare is low, while forest with more volume per hectare gave results that differ more. The results where volume per hectare is large often have fewer plots as a basis for the calculations.

Low site index class ("6 – 8") predict higher BEFs than medium and high site index classes for all species at the same volume per hectare. Site index class "11-14" and "17 and higher" have rather similar BEFs in the same volume classes, especially for spruce.

Table 5. BEFs (Mg m^{-3}) by volume classes and site index (from Marklund and Petersson & Ståhl)

Vol. per ha	Productive Forest								
	Spruce-dominated			Pine-dominated			Broadleaved dominated		
	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →
25	1.071	1.029	1.047	0.873	0.785	0.831	1.046	1.038	1.025
75	1.017	0.954	0.949	0.834	0.782	0.728	1.035	1.010	0.976
125	0.973	0.903	0.910	0.782	0.742	0.726	1.018	0.996	0.964
175	0.921	0.861	0.840	0.758	0.727	0.699	1.015	0.971	0.938
225	0.878	0.825	0.812	0.730	0.702	0.682	0.941	0.933	0.906
275	0.857	0.793	0.794	0.739	0.698	0.672	1.023(*)	0.930	0.919
325	0.830(*)	0.772	0.766	0.723	0.677	0.664	1.065(*)	0.927	0.882
375	0.796(*)	0.769	0.764	0.676	0.670	0.655(*)		0.843(*)	0.907
425		0.760	0.736	0.675(*)	0.666	0.652		0.995	0.915(*)
475		0.751	0.742		0.660	0.626(*)			0.830(*)
625		0.719	0.721	0.762(*)	0.634	0.631(*)		0.882(*)	0.817
100			0.708			0.678(*)			

(*) < 5 plots as basis for the calculation of BEF

A study from Sweden (Jalkanen et al. 2005) compared above-ground biomass calculated from the use of age dependent BEFs (Lethonen, et al. 2004) and biomass equations for individual trees (Marklund 1988) based on data from the Swedish NFI. The results showed that to apply age dependent BEFs at stands that clearly are outside the range of the data used in their development, would lead to bias. An example of this is stands in southern Sweden where stand volume can be higher than 250 m^{3}ha^{-1}, which was the highest volume in the stands used to construct these BEFs. In some of the spruce stands in southern Sweden, the study from Jalkanen (2005) showed that the age dependent BEFs resulted in approximately 30% higher biomass estimation than the biomass obtained from the equations.

In the present study the whole dataset from the period 2006 – 2010 were used and all plots with tree measurements were included, so in principle the BEFs should be applicable for the whole country (except Finnmark County). Lethonen (2005) found that BEFs developed in Finland and Sweden were applicable for regional and national biomass estimation in the two countries, but not for single stands. According to Lethonen, the BEFs should preferably be locally developed if they are going to be used on small areas.

3.3 Models.

The equations for stem, bark, total aboveground and total biomass have high r^2 (coefficient of determination) values for all the main tree species as well as the mixed tree species model (Tables 6 – 9). The equations for below-ground biomass have r^2 values between 0.92 and 0.95, while the equations for other components varied more between the different tree species. Foliage has relatively low r^2 values for the tree equations for pure stands (0.56 – 0.78), but the mixed species model has an r^2 value of 0.89. The equations for pine and spruce have high r^2 values for dead branches and low values for living branches, while the equations for broadleaved species are opposite.

Table 6. *Biomass for pure spruce stands, development class III - V (1*)*

Para-meters	Stem	S.E	Bark	S.E	Living Bran-ches	S.E	Dead Bran-ches	S.E	Foliage	S.E
a	0.2541	0.1165	0.0338^	0.0292	0.3139	0.0883	-0.0717	0.0153	-0.0570^	0.1313
b	0.3098	0.0031	0.1058	0.0024	1.1503	0.0573	0.0087	0.0005	0.5830	0.0280
c	1.0277	0.0017	0.8225	0.0042	0.6069	0.0089	1.0097	0.0094	0.6164	0.0087
d	-0.0077^	0.0071	-0.0076	0.0031	-0.0926	0.0075	0.0108	0.0011	-0.0262	0.0114
$\mathbf{R^2}$	**0.9983**		**0.9596**		**0.7522**		**0.9618**		**0.7799**	
Para-meters	Stump Roots (2*)	S.E	Total under (3*)	S.E	Total above-ground	S.E	Total biom (3*)	S.E		
a	0.4470	0.0578	0.5267	0.1103	2.1234	0.8115	3.0419	1.4751		
b	0.6145	0.0193	0.7422	0.0235	1.2073	0.0397	1.8851	0.0785		
c	0.7832	0.0057	0.7771	0.0057	0.8764	0.0054	0.8507	0.0068		
d	-0.0702	0.0047	-0.0823	0.0067	-0.1533	0.0310	-0.2550	0.0525		
$\mathbf{R^2}$	**0.9239**		**0.9229**		**0.9845**		**0.9749**			

Equations: $W_i = a + b*V^c + d*S$
(where W_i is biomass component in 1000 kg of dry weight, V is stem volume per hectare and S is Site index)
(1) Pure stand defined as stands where 70% of volume or more are spruce*
(2) Stump and roots for bioenergy use. (Spruce and pine = Marklund 1988. For broadleaved species Petersson & Ståhl's below-ground equations are used with reduction of 13% the calculated biomass)*
(3) Total below-ground (stump and roots) based on Petersson & Ståhl equations. Also used in total biomass*
(^)Not significant – 5% level

Table 7. *Biomass for pure pine stands, development class III - V (1*)*

Para-meters	Stem	S.E	Bark	S.E	Living Bran-ches	S.E	Dead Bran-ches	S.E	Foliage	S.E
a	-2.0138	0.1705	0.0386^	0.0399	5.3423	0.2886	-.0143^	0.0204	0.7274	0.0391
b	0.2409	0.0050	0.0647	0.0019	0.4992	0.0497	0.0273	0.0010	0.2514	0.0157
c	1.0666	0.0036	0.8614	0.0057	0.6884	0.0180	0.8328	0.0069	0.6108	0.0119
d	0.3276	0.0209	-.0063^	0.0050	-0.4954	0.0177	0.0011^	0.0026	-0.1007	0.0052
R^2	**0.9928**		**0.9401**		**0.6277**		**0.9031**		**0.6117**	
Para-meters	Stump Roots (2*)	S.E	Total under (3*)	S.E	Total above-ground	S.E	Total biom (3*)	S.E		
a	2.0571	0.0644	2.3114	0.0735	3.6217	0.2663	6.2616	0.3021		
b	0.4228	0.0139	0.4868	0.0151	0.8303	0.0141	1.2918	0.0245		
c	0.8344	0.0063	0.8256	0.0060	0.9150	0.0032	0.8905	0.0036		
d	-0.2684	0.0084	-0.3019	0.0095	-0.4651	0.0310	-0.8079	0.0354		
R^2	**0.9191**		**0.9230**		**0.9866**		**0.9791**			

Equations: $W_i = a + b*V^c + d*S$
(where W_i is biomass component in 1000 kg of dry weight, V is stem volume per hectare and S is Site index)
(1) Pure stand defined as stands where 70% of volume or more are pine*
(2) Stump and roots for bioenergy use. (Spruce and pine = Marklund 1988. For broadleaved species Petersson & Ståhl's below-ground equations are used with reduction of 13% the calculated biomass)*
(3) Total below-ground (stump and roots) based on Petersson & Ståhl equations. Also used in total biomass*
(^)Not significant – 5% level

Table 8. *Biomass for pure broadleaved stands, development class III - V (1*)*

Para-meters	Stem	S.E	Bark	S.E	Living Bran-ches	S.E	Dead Bran-ches	S.E	Foliage	S.E
a	-1.0821	0.0970	-0.0895	0.0149	0.1738^	0.1013	-0.0190	0.0048	-.0003^	0.0012
b	0.2998	0.0041	0.0743	0.0009	0.3615	0.0099	0.0452	0.0023	0.0041	0.0004
c	1.0670	0.0026	1.0024	0.0023	0.8445	0.0056	0.7227	0.0105	1.2403	0.0220
d	0.1512	0.0150	0.0078	0.0021	-0.0596	0.0085	-0.0036	0.0005	-0.0006	0.0002
R^2	**0.9918**		**0.9916**		**0.9412**		**0.6584**		**0.5745**	
Para-meters	Stump Roots (2*)	S.E	Total under (3*)	S.E	Total above-ground	S.E	Total biom (3*)	S.E		
a	0.4838	0.1479	0.5444	0.1705	-0.7097	0.1086	-.0430^	0.2052		
b	0.5379	0.0150	0.6189	0.0172	0.7187	0.0069	1.3110	0.0153		
c	0.8628	0.0056	0.8628	0.0056	0.9915	0.0019	0.9463	0.0023		
d	-0.1035	0.0112	-0.1180	0.0129	0.0375	0.0159	-0.1150	0.0212		
R^2	**0.9489**		**0.9494**		**0.9932**		**0.9913**			

Equations: $W_i = a + b*V^c + d*S$
(where W_i is biomass component in 1000 kg of dry weight, V is stem volume per hectare and S is Site index)
(1) Pure stand defined as stands where 70% of volume or more consist of broadleaved species*
(2) Stump and roots for bioenergy use. (Spruce and pine = Marklund 1988. For broadleaved species Petersson & Ståhl's below-ground equations are used with reduction of 13% the calculated biomass)*
(3) Total below-ground (stump and roots) based on Petersson & Ståhl equations. Also used in total biomass*
(^)Not significant – 5% level

Table 9. *Biomass for mixed species stands, development class III - V (1*)*

Para-meters	Stem	S.E	Bark	S.E	Living Bran-ches	S.E	Dead Bran-ches	S.E	Foliage	S.E
a	-0.8754	0.0384	0.1219	0.0158	3.6458	0.1924	-0.2932	0.0201	-1.3449	0.0126
b	0.3269	0.0025	0.0756	0.0011	0.4708	0.0194	0.0034	0.0002	0.3126	0.0085
c	1.0175	0.0014	0.8685	0.0025	0.7474	0.0075	1.1458	0.0118	0.7235	0.0053
d	0.2905	0.0021	0.0325	0.0003	0.1591	0.0106	0.0199	0.0007	0.0665	0.0031
e	1.0467	0.0019	0.9021	0.0048	0.7935	0.0154	0.3648	0.0150	0.6198	0.0133
f	0.3354	0.0021	0.0707	0.0005	0.1363	0.0058	0.0102	0.0002	0.1169	0.0138
g	1.0633	0.0018	1.0305	0.0029	1.0139	0.0140	0.8181	0.0127	0.0519	0.0016
h	0.1062	0.0054	-0.0055	0.0014	-0.1783	0.0073	0.0320	0.0023	0.0729	0.0005
R^2	**0.9961**		**0.9861**		**0.7961**		**0.8399**		**0.8855**	
Para-meters	Stump Roots (2*)	S.E	Total under (3*)	S.E	Total above-ground	S.E	Total biom (3*)	S.E		
a	2.7840	0.1577	3.2949	0.1760	2.5836	0.1919	5.8227	0.3367		
b	0.3339	0.0092	0.4105	0.0107	1.0721	0.0123	1.4894	0.0212		
c	0.8772	0.0050	0.8685	0.0047	0.8947	0.0021	0.8872	0.0026		
d	0.1775	0.0055	0.1954	0.0064	0.6374	0.0119	0.8659	0.0214		
e	0.9573	0.0084	0.9534	0.0085	0.9470	0.0037	0.9469	0.0046		
f	0.3157	0.0090	0.3631	0.0104	0.6067	0.0100	0.9854	0.0216		
g	0.9430	0.0070	0.9448	0.0068	1.0241	0.0038	0.9964	0.0044		
h	-0.1389	0.0061	-0.1643	0.0068	-0.1664	0.0117	-0.3433	0.0155		
R^2	**0.9305**		**0.9332**		**0.9883**		**0.9811**			

Equations: $W_i = a + b*Vs^c + d*Vp^e + f*Vb^g + h*S$
(where W_i *is biomass component in 1000 kg of dry weight, Vs, Vp and Vb is stem volume from spruce, pine and broadleaved per hectare and S is Site index)*
(1) Mixed stands defined as stands where < 70% of volume from main tree species. Only mixed stands dominated by conifer species are included.*
(2) Roots for bioenergy use. (Marklund 1988)*
(3) Total below-ground (stump and roots) based on Petersson & Ståhl's equations. Also used in total biomass*

The results from the paired t-test for total biomass estimates are presented in tables 10 – 13. Corresponding tables for above-ground biomass, total below-ground biomass and below-ground biomass for bioenergy use are presented in the Appendix (Tables A3 – A14). All these tables show mean values based on the Swedish biomass equations (Marklund 1988; Petersson & Ståhl 2006) in the column "observed". The columns "equations for pure stands" and "equations for mixed stands" shows the difference ("diff" in the tables) between the estimates from the newly developed models and the Swedish equations as well as the relative difference in %, and standard error of the difference. The column "Lethonen" is based on the Finnish equations from Lethonen et. al. (2004) and shows the differences when comparing to the Swedish equations.

As mentioned before, the equations from Finland are based on Marklund's (1988) equations that only cover root biomass that can be extracted for bioenergy, so when analysing the results it is important to keep this in mind. The tables for above-ground biomass (Appendix, Tables

A3, A4, A6) and below-ground biomass for bioenergy (Appendix, Tables A11, A12, A14) are directly comparable though, because all the results here are from equations based on Marklund (1988). Foliage for broadleaved species was not included in the equations developed in Finland for total above-ground biomass, and neither developed as a separate function. The means for total above-ground biomass in the column “Lethonen” (Appendix, Table A5) for broadleaved stands is therefore not directly comparable to the means in the column “observed” in the tables, but the calculated foliage amounts to only 1.3% of the total above-ground biomass. The biomass equations from Finland only covered above-ground components for broadleaved stands because below-ground functions for those tree species were not available when the equations were produced. The tables for broadleaved stands, therefore, do not have not any calculations in the column “Lethonen” for total biomass (Table 12) or below-ground biomass for bioenergy (Appendix, Table A13).

The “observed” values in the tables are later on often described as “the control value”, but it cannot be considered as a true value because it is only an estimate and stem forms for trees in Norway can be different from Sweden. The data material from where Marklund’s (1988) equations were developed also have a relatively small number of large trees, and many of the trees in the NFI tree database are outside the diameter range from where the equations were developed. The real biomass values are unknown and in areas in Norway very different from where the equations were developed, it is possible that the calculated values from the Swedish equations are biased. A study in southern Finland (Liu & Westman 2009) revealed that Marklunds equations overestimated crown biomass while stem and stump components was highly underestimated. But the result can show the forest types (main species, stand age, site index, volume classes) and regions in the country where the new stand-level models predicts similar biomass to the Swedish tree-level equations, and where they don’t.

In the coniferous stands, the developed models predict lower biomass than the Swedish equations (Marklund 1988: Petersson and Ståhl 2006) both above- and below-ground when site productivity is low, e.g. site index 6. The relative difference of total biomass (Mg) was -5.4% when the pine stand model was used on pine stands and -11.5% when the mixed species model were used on the same stands (Table 11). Spruce stands and mixed stands dominated by conifer species had relative differences in site index class 6 that varied from 6.3% to 9.2% lower total biomass (Table 10 and 13).

Lethonen’s (2004) equations predict even lower biomass in site index class 6 above-ground (Appendix, Tables A3 – A6) for all species, and have also significant lower means in the estimates for below-ground biomass compared to the Swedish equations for both spruce, pine and mixed stands in site index class 6, 8 and 11 (Appendix, Tables A11, A12, A14). The above-ground equations from Lethonen used on forest defined as pine stands gave significant higher estimates for site index classes 11, 14 and 17, predicting 5.3% - 8.5% higher above-ground biomass than the estimated control value (Appendix, Table A4).

No clear trend was found over age classes except that when the mixed tree species model (see Table 9) was used on stands with more than 70% of the volume from the main species (Tables 10, 11, 12). At high stand ages they all predicted a little lower total biomass, but this was not significant for most of the age classes.. The same pattern can be seen when the models for spruce- and pine-dominated stands were used on mixed stands (Table 13).

The above-ground biomass estimates based on the Finnish equations (Lethonen et al. 2004) for broadleaved stands at all age classes were substantially lower than the control value (Appendix, Table A5). On average the estimates were 13.74% lower. The below-ground biomass estimates from the Finnish equations were also lower than the control value for all the coniferous stands at high stand ages (Appendix, Tables A11, A12, A14).

The t-test gave very similar results for spruce stands between the new stand-level models and the Swedish equations across a broad spectrum of volume values ranging between 50 m^3ha^{-1} and 750 m^3ha^{-1} (Table 10). Spruce stands with very low volume per hectare (0 – 49 m^3ha^{-1}) showed significant differences, both when the models for pure spruce stands and mixed stands were used, 10% and 5.6% higher biomass respectively. The models developed for pine and broadleaved forest gave lower total biomass at high volumes, but there were fewer observations in those classes so not all the differences are significant (Tables 11 – 12). One could expect that the models constructed for mixed species stands would predict more similar values for mixed stands compared to when the species-specific models are used on the same stands, but that is not always the case. For volume classes > 175 m^3ha^{-1} and higher, the mixed stand model predicts rather high biomass estimates and in southern region at elevation of < 250 meters, the model had 7.4% higher calculated biomass compared to the Swedish equations (Table 13). When the models for pure stands were used on the mixed stands, it gave more similar results in the volume classes from 175 to 375 m^3ha^{-1}, but it was significantly lower at small volumes per hectare.

Table 10. *Comparison of models for spruce stands [(1)], total biomass (dev.class III – V)*

Site index	N	Observed [(2)]	Equations for pure stands [(3)]			Equations for mixed stands [(4)]			Lethonen [(5)]		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	38	91.14	-6.83^	-7.50	2.15	-8.40^	-9.21	2.16	-19.70^	-21.62	2.38
8	83	120.55	-2.28	-1.89	1.39	-4.44^	-3.68	1.30	-15.45^	-12.82	1.42
11	83	137.76	1.52	1.11	1.28	-0.23	-0.16	1.27	-9.76^	-7.08	1.28
14	62	165.13	3.48	2.11	1.94	1.24	0.75	1.89	-5.93^	-3.59	2.15
17	65	197.55	4.95^	2.51	1.91	4.84^	2.45	1.88	-1.91	-0.97	2.20
20	50	246.50	-0.05	-0.02	3.15	0.78	0.32	3.01	-3.65	-1.48	2.75
23	21	317.47	2.39	0.75	3.57	9.00^	2.83	4.41	8.58^	2.70	3.47
26	2	234.92	-5.73	-2.44	6.37	-0.16	-0.07	2.78	-8.75	-3.72	1.01
Age[(6)] classes	N	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	13	95.56	2.18	2.28	1.71	-1.29	-1.35	2.12	-7.71^	-8.07	1.88
35	47	116.55	-0.02	-0.02	1.79	-2.77	-2.37	1.82	-9.96^	-8.55	1.77
45	44	197.64	0.17	0.09	3.04	-1.32	-0.67	2.85	-5.73	-2.90	3.05
55	48	234.30	-0.61	-0.26	2.91	2.73	1.17	3.00	-3.67	-1.57	2.72
65	32	217.60	5.85^	2.69	1.96	6.15^	2.83	2.25	-0.18	-0.08	2.40
75	23	167.95	2.95	1.76	2.85	4.28	2.55	2.55	-7.26^	-4.32	2.84
85	11	213.75	5.73	2.68	3.54	6.13	2.87	2.83	-0.33	-0.15	4.33
95	12	128.56	5.35	4.16	2.44	3.41	2.65	2.61	-6.75^	-5.25	2.74
105	27	164.84	4.65	2.82	2.31	4.48	2.72	2.59	-2.54	-1.54	3.43
115	38	151.67	1.26	0.83	2.19	0.51	0.33	2.12	-9.86^	-6.50	2.32
125	23	137.71	-4.90	-3.56	3.46	-7.24^	-5.26	3.19	-18.04^	-13.10	3.51
135	32	155.73	0.13	0.08	2.90	-2.06	-1.32	2.85	-11.50^	-7.39	3.36
145	24	142.29	-4.74	-3.33	3.66	-5.81	-4.08	3.40	-16.92^	-11.89	4.02
175	30	142.54	-3.74	-2.62	2.37	-6.52^	-4.57	2.37	-16.01^	-11.23	2.66
Vol [(7)] classes	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	32	33.79	3.36^	9.95	0.48	1.88^	5.55	0.49	-5.37^	-15.91	0.55
75	87	75.48	0.59	0.78	0.85	-2.12^	-2.80	0.83	-11.75^	-15.56	0.90
125	64	114.81	-1.17	-1.02	1.64	-3.63^	-3.16	1.61	-14.77^	-12.87	1.67
175	61	149.52	0.59	0.40	1.96	-2.25	-1.50	1.83	-12.56^	-8.40	2.03
225	37	190.45	-2.68	-1.40	2.74	-4.35	-2.29	2.50	-14.30^	-7.51	2.79
275	33	221.22	1.67	0.76	3.25	0.60	0.27	3.18	-7.47	-3.37	3.29
325	31	248.85	7.11^	2.86	2.65	9.18^	3.69	2.47	0.88	0.35	2.67
375	16	286.30	3.93	1.37	6.91	3.71	1.29	6.87	0.75	0.26	6.94
425	15	322.09	-2.62	-0.81	5.90	0.12	0.04	5.46	-2.12	-0.66	5.92
475	6	348.20	0.29	0.08	8.13	10.60	3.04	11.75	4.19	1.20	8.33
625	20	430.58	-1.45	-0.34	4.84	8.88	2.06	5.23	14.71^	3.42	4.90
1000	2	603.47	-51.00	-8.45	23.03	-44.99	-7.46	22.54	-13.62	-2.26	19.83
Reg-ions	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	274	166.06	3.78^	2.28	0.84	3.06^	1.84	0.87	-5.46^	-3.29	1.02
Height[(8)]											
0 - 249	58	204.73	13.46^	6.57	1.46	14.10^	6.89	1.66	7.83^	3.82	2.12
250-499	75	187.54	7.00^	3.73	1.54	6.90^	3.68	1.51	-0.70^	-0.37	1.76
500-749	102	143.08	0.76	0.53	1.03	-0.52	-0.37	0.99	-10.05^	-7.02	1.08
=/> 750	39	129.80	-8.38^	-6.46	2.41	-10.79^	-8.31	2.35	-21.70^	-16.71	2.49
MID- [(8)]	77	133.50	-2.58	-1.93	1.48	-3.99^	-2.99	1.34	-13.59^	-10.18	1.53
WEST	29	296.79	-18.00^	-6.06	4.01	-17.38^	-5.86	3.95	-16.08^	-5.42	3.96
NORTH	24	134.03	-5.59^	-4.17	2.36	-7.49^	-5.59	2.21	-16.28^	-12.15	2.10
ALL AREA	404	166.53	0.56	0.34	0.76	-0.28	-0.17	0.77	-8.37^	-5.03	0.84

1. Spruce stands defined as stands where > 70% of volume from spruce
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund’s and Petersson & Ståhl’s equations.
3. The equations for pure spruce stands (table 6)
4. The equations for mixed stands (table 9)
5. Lethonen = Finnish equations from table 7 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)……….175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation. ^. Significant differences, 5% level.

Table 11. *Comparison of models for pine stands(1) , total biomass (dev.class III – V)*

Site index	N	Observed (2)	Equations for pure stands (3)			Equations for mixed stands (4)			Lethonen (5)		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	64	64.85	-3.49^	-5.37	1.00	-7.44^	-11.48	1.14	-11.62^	-17.93	1.00
8	148	86.44	-0.08	-0.09	0.83	-3.70^	-4.28	0.82	-5.59^	-6.46	0.80
11	83	106.83	0.64	0.60	0.98	-0.53	-0.50	0.84	-1.34	-1.26	1.02
14	37	147.86	1.79	1.21	1.97	4.19^	2.83	1.96	6.81^	4.61	2.38
17	20	155.27	0.25	0.16	2.85	3.93^	2.53	1.75	7.77^	5.01	2.57
20	1	159.59	2.05	1.29	---	17.08	10.70	---	10.95	6.86	---
Age(6) classes	**N**	**Observed**	**Diff**	**Rel d %**	**S Err**	**Diff**	**Rel d %**	**S Err**	**Diff**	**Rel d %**	**S Err**
35	9	57.37	0.30	0.52	1.69	0.35	0.61	1.12	-3.74	-6.51	1.68
45	15	83.34	0.39	0.47	0.98	1.29	1.54	1.27	-1.17	-1.40	1.77
55	35	111.83	-0.17	-0.16	2.18	-0.84	-0.75	1.93	-0.55	-0.49	2.42
65	27	98.19	-1.06	-1.08	1.53	-0.55	-0.56	1.86	-1.73	-1.76	1.96
75	12	132.80	-1.51	-1.14	2.71	-3.31	-2.49	2.95	2.45	1.84	4.50
85	14	83.74	0.82	0.98	2.09	-0.65	-0.78	1.43	-2.98	-3.56	2.54
95	20	92.29	-2.34	-2.54	1.92	-5.12^	-5.55	2.04	-6.01^	-6.51	1.70
105	32	91.88	-2.87	-3.12	2.07	-3.50	-3.81	1.76	-6.58^	-7.17	1.86
115	48	96.54	-2.56	-2.65	1.39	-4.13^	-4.28	1.61	-7.04^	-7.30	1.53
125	42	102.94	1.72	1.67	1.88	-1.56	-1.52	2.08	-2.62	-2.54	1.86
135	29	95.05	2.55	2.69	1.37	-1.97	-2.07	1.31	-1.23	-1.30	2.70
145	24	98.64	0.79	0.80	2.56	-2.26	-2.29	2.53	-3.01	-3.05	2.77
175	46	97.92	0.36	0.37	1.20	-3.61^	-3.69	1.31	-5.78^	-5.90	1.44
Vol (7) classes	**N**	**Observed**	**Diff**	**Rel d %**	**S Err**	**Diff**	**Rel d %**	**S Err**	**Diff**	**Rel d %**	**S Err**
25	57	28.19	0.57	2.01	0.47	-0.50	-1.78	0.54	-4.82^	-17.11	0.57
75	89	60.07	-0.89	-1.48	0.82	-3.80^	-6.33	0.84	-7.97^	-13.27	0.87
125	90	93.62	-0.86	-0.92	0.94	-4.02^	-4.29	0.97	-6.43^	-6.87	1.01
175	46	121.48	3.12^	2.57	1.34	-0.06	-0.05	1.28	-0.45	-0.37	1.47
225	27	155.12	0.42	0.27	2.29	-2.86	-1.85	2.65	0.92	0.59	2.50
275	22	188.63	0.24	0.13	3.02	1.70	0.90	3.43	5.83	3.09	3.35
325	9	224.45	-3.61	-1.61	3.27	9.26^	4.13	3.12	7.47	3.33	3.36
375	5	257.55	-4.48	-1.74	10.41	-9.60	-3.73	10.36	8.87	3.44	10.16
425	4	308.56	-24.00	-7.78	16.54	-14.03	-4.55	10.29	-2.20	-0.71	15.56
475	1	317.09	-1.93	-0.61	---	-1.78	-0.56	---	29.30	9.24	---
625	3	359.31	-6.65	-1.85	20.56	-14.38	-4.00	18.34	28.62	7.97	21.70
Regions	**N**	**Observed**	**Diff**	**Rel d %**	**S Err**	**Diff**	**Rel d %**	**S Err**	**Diff**	**Rel d %**	**S Err**
SOUTH	248	99.52	2.16^	2.17	0.57	0.39	0.39	0.54	-0.80	-0.81	0.66
Height(8)											
0 - 249	71	122.78	2.69^	2.19	1.20	1.64	1.33	1.05	1.62	1.32	1.32
250-499	86	114.52	3.07^	2.68	1.12	2.13^	1.86	1.06	1.68	1.47	1.24
500-749	69	71.99	1.58^	2.19	0.75	-1.77^	-2.46	0.66	-3.87^	-5.38	0.90
=/> 750	22	65.45	-0.68	-1.04	1.39	-2.68	-4.10	1.74	-6.91^	-10.56	1.61
MID- (8)	24	70.31	-1.77	-2.52	1.25	-4.20^	-5.97	1.20	-8.19^	-11.64	1.07
WEST	67	106.92	-8.84^	-8.27	1.29	-11.92^	-11.15	1.43	-11.88^	-11.12	1.62
NORTH	14	68.67	-1.46	-2.12	1.25	-2.00	-2.91	1.03	-6.46^	-9.41	1.95
ALL AREA	353	97.72	-0.32	-0.33	0.53	-2.34^	-2.39	0.54	-3.62^	-3.70	0.62

1. Pine stands defined as stands where > 70% of volume from pine
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's equations.
3. The equations for pure pine stands (table 7)
4. The equations for mixed stands (table 9)
5. Lethonen = Finnish equations from table 6 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Table 12. *Comparison of models for broadleaved stand s [(1)], total biomass (dev.class III – V)*

Site index	N	Observed [(2)]	Equations for pure stands [(3)]			Equations for mixed stands [(4)]			Lethonen [(5)]		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	62	35.09	0.24	0.68	0.16	1.29^	3.68	0.23			
8	149	60.13	-0.84^	-1.39	0.30	-1.19^	-1.98	0.33			
11	96	100.13	-1.37^	-1.37	0.63	-3.27^	-3.26	0.59			
14	46	133.03	-1.21	-0.91	1.19	-2.90^	-2.18	1.20			
17	20	134.74	0.80	0.60	2.48	0.18	0.13	2.24			
20	3	196.37	8.64	4.40	2.25	7.76	3.95	3.43			
23	2	193.96	14.35^	7.40	1.09	13.50^	6.96	0.42			
Age [(6)] classes	N	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	71.96	4.84	6.73	2.50	3.54	4.92	2.32			
35	21	57.17	0.74	1.30	0.85	1.07	1.87	0.93			
45	22	51.28	0.65	1.26	0.84	0.38	0.74	0.89			
55	38	86.96	-0.75	-0.86	0.87	-1.62	-1.86	0.87			
65	56	82.63	0.19	0.23	0.86	-0.32	-0.39	0.96			
75	53	68.99	-0.25	-0.36	0.48	-0.70	-1.01	0.54			
85	48	86.67	-1.34	-1.55	1.01	-2.13	-2.46	0.97			
95	52	71.97	-1.13^	-1.57	0.53	-1.71^	-2.37	0.53			
105	41	70.09	-0.91	-1.30	0.61	-1.42^	-2.03	0.58			
115	18	83.51	-2.51	-3.01	1.64	-3.37	-4.03	1.63			
125	8	64.80	-2.13	-3.29	1.68	-2.11	-3.26	1.79			
135	8	71.65	-1.95	-2.73	1.25	-2.45	-3.42	2.22			
145	2	212.77	-4.95	-2.33	5.09	-7.09	-3.33	4.38			
175	3	39.19	0.67	1.70	0.65	3.54	4.92	0.80			
Vol [(7)] classes	**N**	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	140	28.96	0.37^	1.29	0.09	1.25^	4.33	0.13			
75	141	74.12	-0.58^	-0.79	0.26	-2.05^	-2.76	0.25			
125	45	124.24	-1.62	-1.31	0.90	-4.01^	-3.22	0.88			
175	29	170.14	-3.09	-1.81	2.01	-4.92^	-2.89	1.92			
225	12	218.70	-1.44	-0.66	3.06	-3.28	-1.50	3.46			
275	5	248.86	5.29	2.12	5.30	4.96	1.99	5.16			
325	2	334.36	-23.66^	-7.07	0.46	-17.49^	-5.23	0.62			
375	2	373.52	-35.59	-9.53	8.23	-29.85	-7.99	8.96			
425	2	406.65	-7.05	-1.73	22.80	0.70	0.17	27.36			
Regions	**N**	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	113	89.42	0.67	0.74	0.54	0.33	0.37	0.52			
Height[(8)]											
0 - 249	35	171.49	0.97	0.57	1.63	-0.04	-0.02	1.57			
250-499	21	102.45	1.50	1.47	1.46	0.82	0.80	1.36			
500-749	20	83.19	0.04	0.05	0.92	-0.40	-0.48	0.91			
=/> 750	37	42.38	0.45	1.07	0.23	0.64	1.51	0.28			
MID- [(8)]	30	87.17	-3.34	-3.84	1.63	-4.18^	-4.80	1.58			
WEST	88	84.32	-1.70^	-2.01	0.55	-2.86^	-3.40	0.61			
NORTH	147	56.75	-0.39	-0.70	0.27	-0.65^	-1.15	0.30			
ALL AREA	378	75.18	-0.59^	-0.78	0.27	-1.12^	-1.50	0.28			

1. Broadleaved stands defined as stands where > 70% of volume from broadleaved tree species.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's equations.
3. The equation for broadleaved stands (table 8)
4. The equation for mixed stands (table 9)
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)……….175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Table 13. *Comparison of models for mixed stands dominated by conifer species*[(1)]*,*
total biomass (dev.class III – V)

Site index	N	Obser-ved [(2)]	Equations for pure stands [(3)]			Equations for mixed stands [(4)]			Lethonen [(5)]		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	25	64.54	-5.71^	-8.85	1.78	-4.07^	-6.31	1.92	-15.57^	-24.13	1.96
8	69	85.93	-5.25^	-6.11	1.22	-0.70	-0.81	0.88	-13.53^	-15.74	1.19
11	68	115.78	-3.06^	-2.64	1.35	2.96^	2.56	0.97	-10.43^	-9.01	1.24
14	67	132.15	0.52	0.39	1.60	8.15^	6.17	1.12	-4.88^	-3.69	1.41
17	16	186.48	3.33	1.78	5.29	14.09^	7.56	3.60	-1.79	-0.96	4.72
20	7	182.49	9.24	5.06	7.37	15.30	8.39	7.11	2.68	1.47	8.51
23	3	254.77	-5.00	-1.96	13.20	21.82	8.57	16.98	-9.61	-3.77	14.63
Age [(6)] classes	N	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	120.64	-11.77	-9.76	5.58	-5.31	-4.40	4.19	-21.16^	-17.54	5.90
35	23	89.48	0.13	0.14	2.05	3.42^	3.82	1.50	-7.52^	-8.40	1.57
45	29	113.67	-1.91	-1.68	2.17	5.45^	4.80	2.31	-8.72^	-7.67	2.05
55	19	139.37	7.01	5.03	4.25	13.03^	9.35	2.80	1.51	1.09	3.82
65	23	115.13	-2.32	-2.01	2.62	4.53	3.94	2.31	-8.79^	-7.63	2.59
75	17	124.09	0.13	0.11	2.91	6.30^	5.08	2.59	-7.09^	-5.71	2.99
85	20	112.47	-2.06	-1.83	3.12	4.24^	3.77	2.05	-9.04^	-8.04	3.01
95	14	102.17	-2.52	-2.47	4.28	4.66	4.57	3.47	-9.20^	-9.00	3.67
105	15	108.79	-6.40^	-5.88	2.03	0.31	0.28	1.96	-13.10^	-12.04	2.19
115	17	88.33	-4.36	-4.94	3.17	-0.46	-0.52	1.95	-12.88^	-14.59	2.76
125	24	125.62	-3.49	-2.78	2.34	3.70	2.94	1.99	-9.77^	-7.78	2.62
135	19	111.58	-8.81^	-7.90	2.93	-3.50	-3.14	2.83	-17.82^	-15.97	2.76
145	17	111.88	-3.56	-3.18	2.19	0.42	0.38	1.95	-12.73^	-11.38	2.32
175	10	152.92	0.87	-9.76	2.04	11.00^	7.20	2.64	-4.57^	-2.99	1.884
Vol [(7)] classes	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	37	34.12	-1.16	-3.41	0.78	0.21	0.62	0.67	-3.13^	-13.13	0.78
75	67	69.64	-2.65^	-3.80	0.98	-0.21	-0.30	0.80	-4.44^	-8.97	0.91
125	54	105.96	-5.22^	-4.93	1.56	0.11	0.10	1.39	-4.16^	-5.45	1.59
175	41	140.77	-2.47	-1.75	2.25	4.61^	3.27	1.44	-0.87^	-0.85	2.05
225	20	175.93	1.30	0.74	3.83	7.36	4.18	2.58	3.16^	2.44	3.39
275	21	205.56	-0.35	-0.17	4.48	15.10^	7.34	2.70	5.31	3.46	4.05
325	6	251.98	-2.89	-1.15	10.28	20.23^	8.03	5.76	2.39	1.26	9.64
375	6	271.45	5.43	2.00	8.11	20.46^	7.54	3.05	12.21	6.03	6.98
425	2	325.62	-17.27^	-5.30	1.76	24.96	7.67	14.17	1.07	0.44	7.56
475	1	347.61	21.96	6.32	---	44.82	12.89	---	22.26	8.23	---
Reg-ions	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	187	120.65	-0.57	-0.48	0.92	6.67^	5.53	0.76	-7.06^	-5.85	0.86
Height[(8)]											
0 - 249	63	156.74	-0.98	-0.62	1.86	12.59^	7.43	1.43	-4.48^	-2.86	1.67
250-499	60	123.30	1.86	1.51	1.73	7.25^	5.55	1.06	-5.05^	-4.09	1.48
500-749	45	86.51	-1.69	-1.95	1.33	2.14^	2.42	0.88	-9.69^	-11.20	1.16
=/> 750	19	77.17	-3.97	-5.14	2.14	-3.22	-4.35	2.27	-15.08^	-19.54	2.50
MID- [(8)]	37	105.94	-5.54^	-5.23	1.89	-3.70^	-3.49	1.29	-15.96^	-15.06	2.07
WEST	19	86.73	-7.99^	-9.21	2.99	-3.27	-3.77	1.93	-14.21^	-16.38	2.80
NORTH	12	87.62	-9.21^	-10.52	3.54	-5.69	-6.49	2.70	-18.99^	-21.67	3.62
ALL AREA	255	114.25	-2.29^	-2.00	0.80	3.81^	3.34	0.69	-9.46^	-8.28	0.78

1. Mixed stands defined as stands where < 70% of volume from main tree species. Only mixed stands dominated by conifer species are included.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's equations.
3. The equations for pine stands used when pine dominates (table 7) or the equations for spruce (table 6) when spruce is the dominant species in the stand.
4. The equations for mixed stands (table 9)
5. Lethonen = Finnish equations from table 6 and 7 in Lethonen et al.2004 (Same procedure as described above at point 3.).
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)……….175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Most of the new stand level models estimate higher total biomass compared to the control value in region “South”. Elevations of < 250 meters have relative differences for spruce stands of more than 6% (Table 10). The mixed species model also estimated substantially higher total biomass for mixed stands (Table 13), 5.5% on average for the whole region South and 7.4% higher in elevations below 250 meters. If the stands are located higher than 750 meters, all the new models for coniferous on average estimates lower biomass in region “South” (Tables 10, 11, 13), but only spruce stands shows statistically significant differences.

The other regions have opposite results than region “South”. Here all the developed stand-level models estimated lower biomass averages even though not all differences were statistically significant. Region “West” has the largest differences for spruce stands with 6% lower total biomass and pine stands with more than 8% difference (Table 10, 11) when the pure stands models were used. Mixed forest in region “North” also gave negative differences with the use of both the equations for pure stands (- 10.5%), as well as the models developed for stands with mixed tree species, - 6.5% (Table 13).

In general the new models for broadleaved species predicted biomass values very similar to the Swedish equations (Marklund 1988; Petersson & Ståhl 2006) for above-ground (Appendix, Table A5) and total biomass (Table 12) for all regions, while the “Mid”- part of Norway and region “West” had estimates 6.3 – 6.6% lower in below-ground biomass (Appendix, Tables A9, A13).

The Finnish equations (Lethonen et. al. 2004) have large significant differences in estimated biomass when compared to the control value for several classes of volume per hectare, site indexes, age classes, and regions. For example, the below-ground biomass estimates for pine-dominated forest (Appendix, Table A12) are 21 – 25% lower than the control value in the regions “West-“, “Mid-“, and “North”, and in site index class 6 the relative difference is more than 33% lower. In general, the Finnish equations for pine and spruce estimate lower above-ground biomass at low volumes per hectare, and higher when volume per hectare is high (Appendix, Table A3, A4, A6). For forests dominated by broadleaved species, the Finnish equations estimates substantially lower above-ground biomass for all regions, in average - 13.78% (Appendix, Table A5).

The forests in Norway grow under very different climatic conditions and the applied silvicultural treatments vary not only between the regions, but also within regions. Different silvicultural practice in the past have most certainly affected tree structure at stand level, and stand-level models constructed for use in the whole country cannot be expected to work equally well everywhere. In Hedmark and Oppland counties, for example, the forests are more intensively managed than in the counties in the western parts of Norway. There are rather large differences in forest structure between other counties also. E.g. in Vestfold 22% of the productive forest are defined as development class V (Eriksen et. al. 2006) while in Nordland County 43% are in the same class (Andreassen et. al. 2011).

The areas dominated by spruce forest in the middle of Norway may look very similar to spruce forest in the southeast, but clear differences can be found. For example with the same site index classes, the volume per hectare is substantially higher in the region “South” (see Fig. 2) compared to region “Mid-Norway”. This are probably related to the fact that Sør- and Nord-Trøndelag have large areas that are not easily accessible due to lack of forest roads, so these areas are managed less intensive than areas in the southern parts of the country. Spruce stands that have been clear cut after the World War 2 will often have high volumes per area unit because many of these areas were planted relatively densely, and accordingly the production possibilities have been better utilized than previous selective cutting methods.

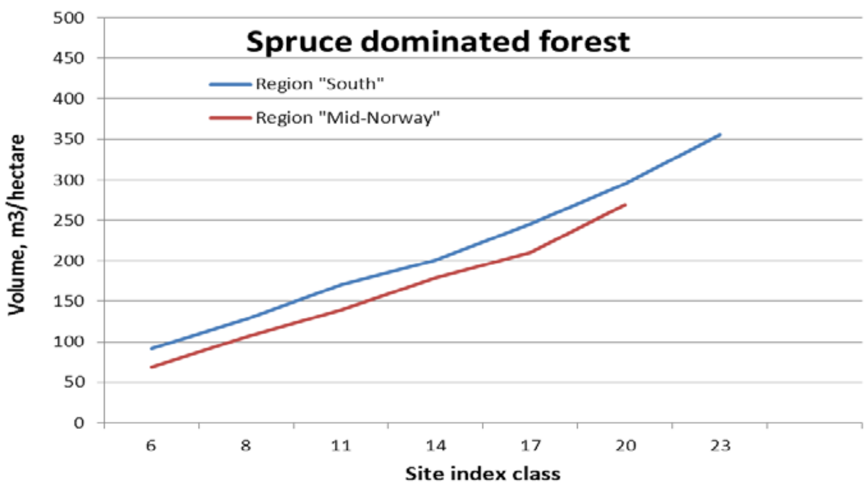


Figure. 2 Volume per hectare at different site index classes for spruce-dominated stands in region “Mid-Norway” and region “South”.

Since the stand-level models developed have volume as an independent variable, the variations in biomass caused by different stand volumes in areas and regions should be accounted for. Areas with the same tree species growing on the same site index, with approximately the same density (volume per hectare), would be expected to have about the same relationship (ratio) between biomass and volume, but that is not the case (see Fig. 3).

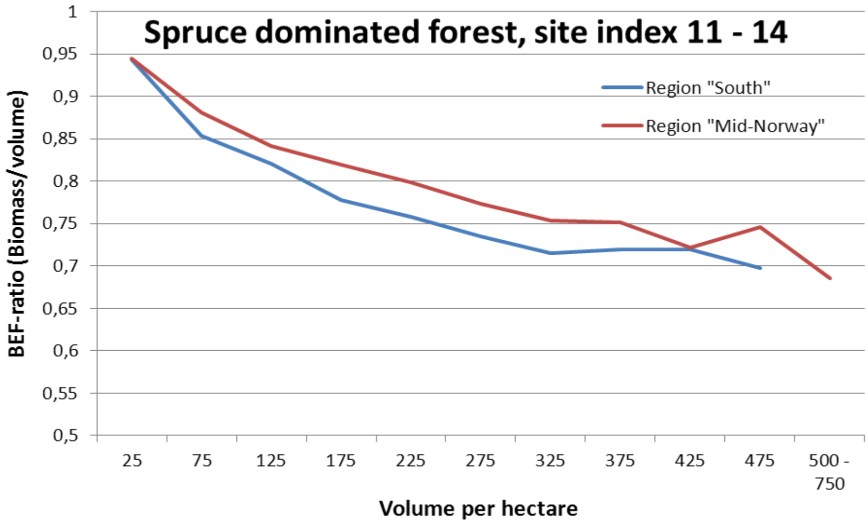


Figure 3. Calculated BEF-ratio between total biomass and total volume in region "South" and "Mid-Norway" at the same volume (m^3) per hectare, Spruce-dominated stands in development class III – V.

The only variables in Marklund's (1988) equations are diameter at breast height and tree height. Therefore differences in calculated biomass when volume per hectare and site index are the same must be due to a different relationship between diameter and height. This means that there are differences in the diameter-height relationship for individual trees between regions even when the species, site indexes, ages and volumes are approximately the same, but the reason for this was not investigated in this study.

The variables "trees per hectare" and "elevation level" were also investigated to see if they improved the fit of the models. Both variables were significant in most of the models with r^2 values that were sometimes slightly higher compared to models with only volume and site index as independent variables. However "trees per hectare" is a variable that is not always present in forest data and when present it is often not very accurate. A t-test was run to see if these variables were included in the models, whether or not they would give estimates for the different regions or elevaton classes more similar to the predictions from the tree-level equations from Sweden but that was not the case. For example the model for pure spruce stands (see Table 6) estimated on average 2.3% higher total biomass in region "South" (Table 10), but a model with the variables trees per hectare and elevation in addition to volume and site index had on average estimates that were 2.6% higher than the Swedish equations. In the regions “Mid-“, “West-“ and “North”, the developed spruce model estimated -1.9%, -6.1% and -4.2% lower total biomass while the model with more variables had -2.8%, -5.9% and -5.2% for the same regions. The results comparing means in different elevation classes in region south were also approximately the same for the two different models.

4.Conclusion

The main aim of this study was to develop stand-level models and BEFs for biomass estimation of forest in Norway. Tree and stand-data measured in the period 2006 – 2010 by the Norwegian National Forest Inventory were used.

BEFs developed in other countries have shown that tree biomass vary with age and tree species. By adding site index as a variable in addition to dominant tree species and stand age, the applicability of the BEFs increases because there are relatively large biomass ratio-differences between low productive sites compared to high productive sites even at the same stand ages. BEFs depending on dominant tree species, site index and volume per hectare were also developed. In general, the BEFs decreased as stand age or volume per hectare increased. The BEFs are also lower at high productive sites compared to low productive sites.

Volume per hectare and site index were chosen as the independent variables to be included in the models with the selected functional form being:

$$\hat{Y} = \beta + \beta_1 \times Volume^{\beta_2} + \beta_3 \times Siteindex$$

where $\hat{Y}$ is the predicted biomass while $\beta, \beta_1, \beta_2, \beta_3$ are the estimated regression parameters. Models were developed for forests with mixed species, and species-specific models for pure stands of pine, spruce, and broadleaved forests.

The models for total biomass, above-ground biomass, and below-ground biomass were tested on a validation dataset with several t-test comparing the biomass estimates with Swedish equations. The new models in general predict biomass estimates similar to the Swedish equations for a broad spectrum of values over stand age, volume per hectare, and site index.

The models are developed from a large and country representative dataset and can be used over the whole country except Finnmark. The new models in general estimate total biomass more similarly to the Swedish equations compared to the Finnish stand-level biomass equations. However, in some areas the new models give significant differences from the Swedish equations, and the areas where this most often occurs are in the western region, in site index class 6 and at elevation > 750 meters in the south-east region.

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Appendix

Table A1. BEFs (Mg m^{-3}) by stand age classes and site index (Repola)

Age class	Productive Forest								
	Spruce-dominated			Pine-dominated			Broadleaved dominated		
	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →
1-9	0.841	0.853	0.789	0.713	0.739	0.582	0.848	0.836	0.852
10-19	0.961	0.868	0.878	0.730	0.633	0.685	0.889	0.841	0.826
20-29	0.925	0.876	0.828	0.737	0.662	0.704	0.830	0.835	0.795
30-39	0.931	0.843	0.771	0.725	0.694	0.670	0.827	0.815	0.791
40-49	0.895	0.806	0.708	0.750	0.699	0.647	0.832	0.817	0.775
50-59	0.903	0.775	0.676	0.739	0.697	0.636	0.856	0.818	0.775
60-69	0.872	0.750	0.658	0.751	0.672	0.626	0.832	0.823	0.787
70-79	0.877	0.741	0.657	0.749	0.670	0.602(*)	0.841	0.833	0.783
80-89	0.907	0.723	0.650	0.738	0.675		0.849	0.843	0.797
90-99	0.865	0.733	0.619	0.742	0.664	0.664	0.856	0.839	0.798(*)
100-109	0.863	0.708	0.629	0.722	0.670	0.604	0.867	0.834	0.749(*)
110-119	0.829	0.718	0.615	0.711	0.654	0.584(*)	0.881	0.814	0.817
120-129	0.849	0.710	0.606	0.700	0.645	0.607(*)	0.856	0.792	
130-139	0.829	0.685	0.639(*)	0.697	0.631		0.875	0.843	
140-149	0.837	0.705		0.704	0.637		0.862	0.856	0.858(*)
> 150	0.822	0.708	0.618(*)	0.691	0.624	0.582(*)	0.838	0.656(*)	

(*) < 5 plots as basis for the calculation of BEF

Table A2. BEFs (Mg m^{-3}) by volume classes and site index (Repola)

Vol. per ha	Productive Forest								
	Spruce-dominated			Pine-dominated			Broadleaved dominated		
	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →	Site index 6 - 8	Site index 11 - 14	Site index 17 →
25	0.926	0.902	0.922	0.754	0.700	0.737	0.852	0.853	0.847
75	0.886	0.837	0.835	0.737	0.702	0.666	0.854	0.841	0.817
125	0.853	0.796	0.801	0.705	0.677	0.669	0.849	0.835	0.818
175	0.814	0.761	0.745	0.691	0.669	0.650	0.864	0.820	0.794
225	0.778	0.731	0.720	0.673	0.651	0.639	0.819	0.796	0.778
275	0.759	0.704	0.705	0.679	0.648	0.634	0.900(*)	0.800	0.787
325	0.741(*)	0.683	0.678	0.669	0.631	0.622	0.883(*)	0.798	0.764
375	0.710(*)	0.682	0.675	0.633	0.627	0.616(*)		0.736(*)	0.783
425		0.672	0.649	0.622(*)	0.619	0.606			0.785(*)
475		0.662	0.655		0.614	0.588 (*)			0.722 (*)
625		0.632	0.631	0.689(*)		0.577(*)		0.755(*)	0.715
100			0.616			0.635(*)			

(*) < 5 plots as basis for the calculation of BEF

Table A3. *Comparison of models for spruce stands(1), above-ground biomass (dev.class III – V)*

Site index	N	Observed (2)	Functions for pure stands (3)			Functions for mixed stands (4)			Lethonen (5)		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	38	64.60	-3.73^	-5.77	1.29	-4.93^	-7.63	1.29	-8.79^	-13.61	1.29
8	83	86.84	-0.60	-0.69	0.82	-2.09^	-2.41	0.76	-4.83^	-5.57	0.80
11	83	101.06	1.25	1.23	0.78	0.17	0.17	0.77	-1.28	-1.26	0.82
14	62	122.61	2.00	1.63	1.21	0.81	0.66	1.18	1.42	1.15	1.51
17	65	147.77	2.68^	1.81	1.13	2.66^	1.80	1.06	4.54^	3.07	1.45
20	50	184.32	-0.34	-0.19	1.81	0.26	0.14	1.70	4.65^	2.52	1.59
23	21	240.83	-0.08	-0.03	2.32	3.50	1.45	2.55	12.58^	5.22	2.47
26	2	172.44	-1.35	-0.78	2.13	2.20	1.27	2.53	3.58	2.07	3.63
Age (6) classes	N	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	13	70.86	0.51	0.72	1.19	-1.18	-1.66	1.37	-2.28	-3.22	1.45
35	47	86.26	-0.81	-0.93	1.14	-2.15	-2.50	1.16	-3.12^	-3.62	1.14
45	44	147.47	-0.35	-0.24	1.75	-1.19	-0.81	1.63	1.92	1.30	1.85
55	48	175.50	-0.97	-0.55	1.77	0.85	0.49	1.73	3.92^	2.23	1.74
65	32	163.19	3.12^	1.91	1.08	3.35^	2.05	1.18	6.03^	3.69	1.65
75	23	124.18	2.00	1.61	1.58	2.61	2.10	1.35	1.01	0.81	1.73
85	11	159.60	3.77	2.36	2.16	3.65	2.28	1.75	6.49	4.07	3.22
95	12	94.56	3.57^	3.77	1.42	2.29	2.42	1.48	0.45	0.47	1.93
105	27	122.67	3.04^	2.48	1.40	2.72	2.22	1.35	3.69	3.01	2.43
115	38	111.07	1.52	1.36	1.31	0.89	0.80	1.29	-0.55	-0.49	1.58
125	23	99.79	-2.66	-2.66	2.07	-4.15^	-4.16	1.93	-6.45^	-6.47	2.06
135	32	113.67	1.01	0.89	1.69	-0.46	-0.41	1.65	-1.27	-1.12	2.12
145	24	102.24	-1.37	-1.34	2.31	-2.18	-2.14	2.18	-4.49	-4.39	2.70
175	30	103.22	-1.42	-1.38	1.38	-3.11^	-3.01	1.37	-4.57^	-4.43	1.68
Vol (7) classes	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	32	24.46	1.85^	7.57	0.35	0.66	2.70	0.34	-2.18^	-8.92	0.35
75	87	54.51	0.24	0.45	0.53	-1.40^	-2.57	0.52	-4.67^	-8.56	0.54
125	64	83.07	-0.43	-0.51	1.02	-1.88	-2.26	1.01	-4.97^	-5.98	1.03
175	61	109.39	0.67	0.61	1.18	-0.83	-0.76	1.14	-2.57^	-2.35	1.22
225	37	139.49	-0.93	-0.66	1.61	-1.78	-1.28	1.48	-2.23	-1.60	1.63
275	33	163.98	1.35	0.83	1.84	0.85	0.52	1.79	2.47	1.51	1.87
325	31	186.43	4.22^	2.26	1.59	5.29^	2.84	1.44	7.93^	4.25	1.59
375	16	214.11	2.79	1.30	3.86	2.47	1.15	3.73	9.19^	4.29	3.87
425	15	240.58	-1.09	-0.45	3.25	0.44	0.18	3.03	8.24^	3.42	3.28
475	6	259.57	2.30	0.88	4.69	8.15	3.14	5.18	14.36^	5.53	4.60
625	20	327.35	-2.84	-0.87	2.95	2.43	0.74	2.94	18.49^	5.65	3.04
100	2	454.54	-33.74	-7.42	11.90	-31.89	-7.02	11.77	3.17	0.70	9.54
Regions	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	274	123.31	2.26^	1.84	0.50	1.81^	1.47	0.49	1.79^	1.45	0.68
Height(8)											
0 - 249	58	154.98	7.44^	4.80	0.85	7.81^	5.04	0.84	10.47^	6.75	1.44
250-499	75	140.65	3.70^	2.63	0.93	3.63^	2.58	0.86	4.82^	3.43	1.22
500-749	102	105.07	0.74	0.71	0.66	-0.01	-0.01	0.60	-1.39	-1.32	0.76
=/> 750	39	92.58	-4.01^	-4.33	1.48	-5.50^	-5.94	1.44	-8.23^	-8.89	1.54
MID-	77	97.01	-0.91	-0.94	0.88	-1.87^	-1.93	0.82	-3.52^	-3.63	0.94
WEST	29	220.46	-11.23^	-5.10	2.40	-11.01^	-4.99	2.37	-2.21	-1.00	2.59
NORTH	24	97.59	-3.31^	-3.39	1.44	-4.52^	-4.64	1.38	-5.78^	-5.92	1.11
ALL AREA	404	123.14	0.43	0.35	0.45	-0.12	-0.10	0.45	0.05	0.04	0.55

1. Spruce stands defined as stands where > 70% of volume from spruce
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pure spruce stands (table 6).
4. The functions for mixed stands (table 9).
5. Lethonen = Finnish functions from table 7 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)……….175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation . ^. Significant differences, 5% level.

Table A4. *Comparison of models for pine stands(1), above-ground biomass (dev.class III – V)*

Site index	N	Observed (2)	Functions for pure stands (3)			Functions for mixed stands (4)			Lethonen (5)		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	64	45.84	-2.05^	-4.48	0.63	-5.11^	-11.15	0.74	-4.11^	-8.97	0.59
8	148	62.48	0.16	0.25	0.49	-2.97^	-4.75	0.52	0.74	1.19	0.54
11	83	78.26	0.50	0.64	0.56	-1.35^	-1.72	0.52	4.12^	5.26	0.69
14	37	111.52	-0.54	-0.49	1.07	-0.65	-0.58	1.33	9.00^	8.07	1.44
17	20	117.07	-1.37	-1.17	1.31	-0.68	-0.58	1.12	9.96^	8.50	1.36
20	1	123.48	-3.03	-2.45	---	7.06	5.72	---	9.45	7.65	---
Age (6) classes	N	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
35	9	41.56	0.17	0.41	1.13	-0.41	-0.99	0.80	0.49	1.18	1.14
45	15	61.72	-0.38	-0.62	0.54	-0.40	-0.64	0.80	2.51	4.07	1.37
55	35	83.47	-1.36	-1.63	1.17	-2.86^	-3.43	1.05	3.40^	4.08	1.42
65	27	72.89	-1.53	-2.10	0.85	-2.00	-2.75	1.09	2.45	3.36	1.30
75	12	99.37	-2.11	-2.12	1.64	-5.33	-5.36	2.58	5.94	5.98	3.36
85	14	61.76	-0.17	-0.28	1.28	-1.94^	-3.13	0.89	1.37	2.21	1.83
95	20	66.67	-1.09	-1.64	1.14	-3.85^	-5.77	1.29	0.77	1.16	1.32
105	32	66.52	-1.64	-2.46	1.28	-2.95^	-4.43	1.17	0.14	0.21	1.37
115	48	69.91	-1.50	-2.14	0.81	-3.46^	-4.95	0.99	0.02	0.02	1.06
125	42	75.09	1.22	1.63	1.03	-1.83	-2.43	1.19	3.27^	4.36	1.11
135	29	69.75	1.44	2.07	0.78	-2.56^	-3.67	0.97	3.51	5.04	1.75
145	24	72.07	0.47	0.65	1.43	-2.38	-3.30	1.48	2.59	3.59	1.80
175	46	70.35	0.96	1.37	0.71	-2.41^	-3.43	0.79	1.67	2.37	1.04
Vol (7) classes	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	57	20.10	0.10	0.52	0.32	-0.93^	-4.64	0.37	-1.69^	-8.41	0.37
75	89	43.02	-0.67	-1.57	0.53	-3.01^	-6.99	0.55	-2.14^	-4.97	0.56
125	90	67.52	-0.18	-0.27	0.59	-3.00^	-4.45	0.62	0.70	1.03	0.62
175	46	89.27	1.87^	2.09	0.69	-1.21	-1.35	0.72	5.25^	5.88	0.77
225	27	114.53	0.06	0.05	1.31	-3.47^	-3.03	1.53	7.15^	6.24	1.36
275	22	141.30	-1.32	-0.93	1.60	-2.29	-1.62	1.97	10.16^	7.19	1.76
325	9	167.55	-3.13	-1.87	1.46	2.76	1.65	1.50	12.90^	7.70	1.35
375	5	191.95	-3.44	-1.79	4.65	-10.34	-5.39	4.72	15.17^	7.90	4.36
425	4	224.41	-11.35	-5.06	10.05	-9.87	-4.40	7.01	13.58	6.05	9.26
475	1	243.58	-6.48	-2.66	---	-13.01	-5.34	---	25.32	10.39	---
625	3	275.12	-9.78	-3.56	7.27	-21.95	-7.98	5.96	25.83	9.39	7.86
Regions	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	248	73.24	1.09^	1.49	0.32	-0.96^	-1.31	0.31	3.85^	5.26	0.44
Height(8)											
0 - 249	71	90.92	1.25	1.37	0.67	-0.63	-0.69	0.59	6.14^	6.76	0.87
250-499	86	84.96	1.36^	1.60	0.59	-0.24	-0.28	0.62	5.72^	6.74	0.73
500-749	69	52.22	0.99^	1.90	0.45	-1.81^	-3.46	0.41	1.09	2.09	0.63
=/> 750	22	46.56	0.05	0.10	0.97	-1.89	-4.06	1.14	-0.71	-1.52	1.25
MID-	24	50.23	-0.88	-1.75	0.74	-2.94^	-5.85	0.74	-1.59^	-3.17	0.70
WEST	67	77.07	-5.41^	-7.01	0.80	-8.64^	-11.21	0.95	-2.86^	-3.71	1.12
NORTH	14	49.41	-0.81	-1.63	0.74	-2.08^	-4.22	0.65	-0.71	-1.43	1.36
ALL AREA	353	71.46	-0.34	-0.48	0.30	-2.59^	-3.62	0.33	2.04^	2.85	0.41

1. Pine stands defined as stands where > 70% of volume from pine
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. Viken 1 = The functions for pure pine stands (table 7)
4. Viken 2 = The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 6 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. Significant differences, 5% level.

Table A5. *Comparison of models for broadleaved stands [(1)], above-ground biomass (dev.class III – V)*

Site index	N	Obser-ved [(2)]	Functions for pure stands [(3)]			Functions for mixed stands [(4)]			Lethonen [(5)]		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	62	22.53	0.36^	1.58	0.10	1.32^	5.86	0.10	-2.45^	-10.89	0.28
8	149	40.08	-0.51^	-1.28	0.13	-0.12	-0.31	0.12	-5.72^	-14.28	0.36
11	96	68.19	-0.59	-0.86	0.31	-0.83^	-1.22	0.27	-9.82^	-14.40	0.66
14	46	91.43	0.30	0.32	0.77	0.35	0.39	0.75	-12.41^	-13.57	1.33
17	20	95.26	0.08	0.08	1.03	0.64	0.67	0.87	-13.22^	-13.88	2.86
20	3	143.41	1.87	1.30	0.90	2.96	2.07	1.54	-18.51^	-12.91	4.10
23	2	144.68	3.04	2.10	0.43	4.01	2.77	0.61	-17.78^	-12.29	4.25
Age [(6)] classes	N	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	51.77	1.15	2.22	0.69	0.79	1.52	0.87	-6.18^	-11.94	1.59
35	21	39.22	0.38	0.98	0.35	0.90^	2.29	0.37	-4.94^	-12.59	1.50
45	22	34.65	0.24	0.68	0.24	0.42	1.22	0.29	-4.39^	-12.66	0.91
55	38	59.39	-0.49	-0.83	0.34	-0.19	-0.32	0.29	-8.50^	-14.32	1.11
65	56	56.18	0.46	0.82	0.48	0.86	1.54	0.48	-7.18^	-12.77	1.10
75	53	46.27	0.16	0.35	0.31	0.55	1.19	0.32	-6.04^	-13.06	0.77
85	48	58.76	-0.60	-1.03	0.40	-0.27	-0.46	0.37	-8.45^	-14.39	1.12
95	52	48.33	-0.48	-0.99	0.35	-0.16	-0.33	0.29	-6.87^	-14.22	0.91
105	41	47.41	-0.76^	-1.61	0.25	-0.40	-0.84	0.25	-6.98^	-14.71	0.91
115	18	55.55	-0.70	-1.26	1.11	-0.42	-0.75	1.04	-8.09^	-14.56	1.30
125	8	43.27	-1.35	-3.12	0.72	-0.63	-1.46	0.67	-6.88^	-15.90	2.17
135	8	47.30	0.02	0.05	0.57	0.32	0.67	0.26	-6.26^	-13.24	2.12
145	2	147.47	-1.34	-0.91	2.49	-0.79	-0.53	2.31	-21.60^	-14.65	2.09
175	3	25.96	-0.13	-0.51	0.61	0.56	2.18	0.60	-3.38^	-13.02	0.41
Vol [(7)] classes	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	140	18.80	0.15^	0.78	0.07	0.82^	4.35	0.08	-2.16^	-11.51	0.12
75	141	49.73	-0.41^	-0.81	0.15	-0.49^	-0.98	0.15	-7.03^	-14.14	0.20
125	45	84.71	-0.50	-0.59	0.62	-0.69	-0.81	0.58	-12.08^	-14.26	0.62
175	29	116.28	-0.03	-0.03	1.13	0.50	0.43	1.02	-16.11^	-13.85	1.16
225	12	153.22	-0.12	-0.08	0.98	0.43	0.28	0.98	-21.41^	-13.97	0.76
275	5	179.03	1.35	0.75	1.61	3.19	1.78	1.39	-23.78^	-13.28	1.80
325	2	228.24	-6.39	-2.80	0.80	-0.04	-0.02	0.92	-37.16^	-16.28	1.94
375	2	255.13	-12.19^	-4.78	0.47	-6.44^	-2.52	0.96	-46.09^	-18.07	0.76
425	2	296.82	-7.56	-2.55	8.96	-0.59	-0.20	12.19	-47.89^	-16.14	8.11
Reg-ions	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	113	61.85	0.01	0.02	0.23	0.65^	1.05	0.21	-8.37^	-13.54	0.79
Height[(8)]											
0 - 249	35	121.18	-0.06	-0.05	0.66	0.75	0.62	0.59	-16.86^	-13.92	1.70
250-499	21	71.53	-0.02	-0.03	0.61	0.66	0.93	0.53	-9.82^	-13.72	1.48
500-749	20	57.34	-0.57	-1.00	0.47	0.06	0.10	0.40	-8.24^	-14.37	1.50
=/> 750	37	27.76	0.27	0.98	0.17	0.80^	2.90	0.19	-3.30^	-11.87	0.35
MID-	30	58.73	-1.46^	-2.48	0.68	-1.21	-2.05	0.63	-9.23^	-15.71	1.71
WEST	88	56.25	0.05	0.09	0.39	0.05	0.09	0.37	-7.57^	-13.46	0.67
NORTH	147	37.88	-0.29^	-0.77	0.13	0.08	0.20	0.13	-5.23^	-13.81	0.36
ALL AREA	378	50.87	-0.20	-0.39	0.14	0.15	0.30	0.13	-7.01^	-13.78	0.35

1. Broadleaved stands defined as stands where > 70% of volume from broadleaved tree species.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for broadleaved stands (table 8)
4. The functions for mixed stands (table 9)
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Table A6. *Comparison of models mixed stands dominated by conifer species [1], above-ground biomass (dev.class III – V)*

Site index	N	Observed [2]	Functions for pure stands [3]			Functions for mixed stands [4]			Lethonen [5]		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	25	44.90	-2.91^	-6.49	1.08	-2.44	-5.43	1.18	-6.54^	-14.56	1.09
8	69	61.28	-2.92^	-4.77	0.79	-0.41	-0.67	0.57	-4.66^	-7.60	0.71
11	68	83.79	-1.29	-1.54	0.92	1.75^	2.09	0.61	-1.55	-1.85	0.86
14	67	97.69	-0.05	-0.06	1.06	4.27^	4.37	0.68	1.58	1.62	0.99
17	16	139.86	0.87	0.62	3.29	7.01^	5.01	1.93	4.01	2.86	2.82
20	7	138.01	4.39	3.18	4.47	6.99	5.06	3.55	6.17	4.47	5.45
23	3	193.17	-6.92	-3.58	6.60	8.84	4.58	8.96	-2.37	-1.23	8.01
Age [6] classes	N	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	87.03	-7.33	-8.43	3.52	-4.15	-4.76	2.66	-9.39	-10.79	3.30
35	23	65.52	-0.10	-0.15	1.30	1.43	2.19	0.81	-1.52	-2.32	0.98
45	29	83.89	-1.88	-2.24	1.39	2.22	2.65	1.21	-1.96	-2.33	1.31
55	19	104.67	3.29	3.14	2.65	6.53^	6.24	1.39	5.19	4.96	2.46
65	23	84.01	-1.27	-1.52	1.58	2.26	2.69	1.28	-1.01	-1.20	1.65
75	17	91.49	-0.29	-0.32	1.74	2.91	3.18	1.38	-0.19	-0.21	1.87
85	20	82.10	-1.23	-1.50	2.02	2.14	2.61	1.20	-1.36	-1.65	1.87
95	14	74.36	-1.58	-2.12	2.78	2.29	3.08	2.30	-1.78	-2.40	2.62
105	15	78.50	-3.71^	-4.72	1.47	0.04	0.05	1.33	-3.79	-4.82	1.50
115	17	63.23	-2.42	-3.82	2.04	-0.33	-0.52	1.17	-4.24	-6.71	1.62
125	24	91.11	-1.55	-1.70	1.63	2.50	2.75	1.23	-0.75	-0.82	1.93
135	19	79.64	-4.93^	-6.19	1.89	-1.97	-2.47	1.75	-6.41	-8.05	1.71
145	17	79.77	-0.73	-0.92	1.69	1.09	1.37	1.17	-2.39	-2.99	1.88
175	10	112.13	1.04	0.93	1.57	7.04^	6.28	1.46	3.53	3.15	1.76
Vol [7] classes	**N**	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	37	23.81	-0.57	-2.37	0.50	-0.22	-0.93	0.42	-3.13^	-13.13	0.43
75	67	49.48	-1.36^	-2.75	0.64	-0.32	-0.65	0.50	-4.44^	-8.97	0.56
125	54	76.24	-2.99^	-3.92	0.97	0.07	0.10	0.83	-4.16^	-5.45	0.94
175	41	102.79	-1.35	-1.31	1.46	2.51^	2.44	0.91	-0.87	-0.85	1.29
225	20	129.54	1.28	0.99	2.31	4.33^	3.34	1.44	3.16	2.44	2.01
275	21	153.45	-1.25	-0.81	2.81	7.88^	5.13	1.68	5.31^	3.46	2.48
325	6	189.22	-3.66	-1.93	6.10	9.94^	5.26	2.77	2.39	1.26	5.67
375	6	202.37	4.28	2.12	6.51	11.65^	5.76	1.95	12.21	6.03	5.53
425	2	244.01	-13.24	-5.42	5.77	12.23	5.01	4.30	1.07	0.44	10.17
475	1	270.61	7.65	2.83	---	18.83	6.96	---	22.26	8.23	---
Regions	**N**	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	187	88.62	-0.52	-0.59	0.59	3.55^	4.01	0.42	0.01	0.01	0.56
Height [8]											
0 - 249	63	116.56	-1.48	-1.27	1.16	6.48^	5.56	0.74	2.12	1.82	1.07
250-499	60	91.04	0.77	0.85	1.14	3.78^	4.15	0.64	1.24	1.37	1.02
500-749	45	62.32	-0.71	-1.14	0.89	1.34^	2.15	0.52	-2.28^	-3.66	0.72
=/> 750	19	53.62	-0.94	-1.75	1.33	-1.25	-2.34	1.39	-5.05^	-9.42	1.39
MID-	37	75.62	-2.51	-3.32	1.29	-2.10^	-2.78	0.92	-5.37^	-7.10	1.47
WEST	19	61.54	-4.30^	-6.99	1.79	-2.17	-3.53	1.18	-4.83^	-7.85	1.63
NORTH	12	62.38	-5.68^	-9.11	2.50	-4.14^	-6.64	1.88	-8.72^	-13.99	2.21
ALL AREA	255	83.34	-1.35^	-1.62	0.51	1.93^	2.31	0.39	-1.55^	-1.86	0.51

1. Mixed stands defined as stands where < 70% of volume from main tree species. Only mixed stands dominated by conifer species are included.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pine stands used when pine dominates (table 7,) or the functions for spruce (table 6) when spruce is the dominant species in the stand.
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 6 and 7 in Lethonen et al.2004 (Same procedure as described above at point 3).
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Table A7. *Comparison of models for spruce stands [1], total below-ground biomass (dev.class III – V)*

Site index	N	Observed [2]	Functions for pure stands [3]			Functions for mixed stands [4]			Lethonen [5]		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	38	26.54	-3.23^	-12.19	0.91	-3.65^	-13.76	0.91			
8	83	33.71	-1.79^	-5.31	0.59	-2.66^	-7.90	0.57			
11	83	36.70	0.22	0.60	0.54	-0.64	-1.74	0.53			
14	62	42.52	1.47	3.45	0.79	0.19	0.46	0.76			
17	65	49.77	2.33^	4.68	0.84	1.77^	3.56	0.83			
20	50	62.19	0.42	0.68	1.41	0.24	0.38	1.38			
23	21	76.63	2.76	3.61	1.37	5.18^	6.75	1.95			
26	2	62.48	-4.14	-6.63	4.25	-2.67^	-4.27	0.11			
Age [6] classes	N	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	13	24.70	1.77^	7.18	0.58	-0.17	-0.67	0.81			
35	47	30.29	0.85	2.80	0.68	-0.71	-2.35	0.68			
45	44	50.17	0.60	1.20	1.34	-0.38	-0.76	1.27			
55	48	58.80	0.46	0.79	1.18	1.48	2.51	1.29			
65	32	54.41	2.76^	5.08	1.06	2.52^	4.64	1.20			
75	23	43.76	0.91	2.09	1.36	1.16	2.66	1.27			
85	11	54.15	1.97	3.64	1.47	2.02	3.73	1.08			
95	12	34.01	1.73	5.09	1.07	0.77	2.26	1.15			
105	27	42.17	1.59	3.77	0.98	1.44	3.40	1.20			
115	38	40.61	-0.34	-0.84	0.96	-0.73	-1.80	0.89			
125	23	37.92	-2.36	-6.23	1.43	-3.41^	-9.00	1.30			
135	32	42.06	-0.98	-2.32	1.28	-1.89	-4.48	1.26			
145	24	40.05	-3.49	-8.72	1.48	-3.85^	-9.62	1.37			
175	30	39.32	-2.44^	-6.21	1.04	-3.64^	-9.25	1.05			
Vol [7] classes	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	32	9.33	1.48^	15.91	0.20	1.21^	12.98	0.18			
75	87	20.98	0.32	1.52	0.34	-0.85^	-4.08	0.32			
125	64	31.74	-0.81	-2.54	0.65	-1.99^	-6.27	0.62			
175	61	40.13	-0.13	-0.33	0.82	-1.71^	-4.26	0.73			
225	37	50.96	-1.81	-3.54	1.19	-2.97^	-5.82	1.06			
275	33	57.24	0.29	0.51	1.44	-0.65	-1.13	1.40			
325	31	62.42	2.91^	4.66	1.16	3.28^	5.25	1.10			
375	16	72.19	1.16	1.60	3.24	0.66	0.91	3.23			
425	15	81.52	-1.44	-1.76	2.72	-0.65	-0.79	2.48			
475	6	88.64	-1.88	-2.12	5.46	2.07	2.33	7.32			
625	20	103.22	1.71	1.66	1.97	6.06^	5.87	2.26			
100	2	148.94	-16.57	-11.13	11.10	-12.80	-8.59	10.7			
Regions	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	274	42.75	1.51^	3.52	0.37	0.93^	2.18	0.40			
Height[8]											
0 - 249	58	49.75	6.11^	12.28	0.67	5.85^	11.76	0.83			
250-499	75	46.89	3.31^	7.07	0.64	2.90^	6.19	0.65			
500-749	102	38.01	-0.04	-0.12	0.44	-0.76	-1.99	0.44			
=/> 750	39	37.22	-4.50^	-12.08	0.98	-5.49^	-14.74	0.97			
MID-	77	36.49	-1.72^	-4.72	0.63	-2.36^	-6.46	0.57			
WEST	29	76.33	-6.57^	-8.60	1.83	-6.57^	-8.61	1.79			
NORTH	24	36.44	-2.29^	-6.29	0.98	-3.14^	-8.62	0.90			
ALL AREA	404	43.39	0.13	0.29	0.33	-0.44	-1.01	0.34			

1. Spruce stands defined as stands where > 70% of volume from spruce
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pure spruce stands (table 6)
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 7 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Table A8. *Comparison of models for pine stands[(1)], total below-ground biomass (dev.class III – V)*

Site index	N	Observed [(2)]	Functions for pure stands [(3)]			Functions for mixed stands [(4)]			Lethonen [(5)]		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	64	19.01	-1.56^	-8.19	0.39	-3.79^	-19.93	0.49			
8	148	23.96	-0.31	-1.29	0.36	-2.86^	-11.93	0.37			
11	83	28.57	0.17	0.58	0.46	-1.86^	-6.50	0.41			
14	37	36.35	2.49^	6.85	1.08	1.12	3.07	0.99			
17	20	38.19	1.89	4.94	1.65	0.71	1.86	1.09			
20	1	36.11	5.43	15.03	---	6.71	18.57	---			
Age [(6)] classes	N	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
35	9	15.81	0.21	1.35	0.69	-0.63	-3.96	0.58			
45	15	21.62	0.89	4.13	0.58	-0.33	-1.51	0.52			
55	35	28.36	1.28	4.51	1.09	-0.77	-2.70	0.94			
65	27	25.31	0.57	2.25	0.81	-0.90	-3.54	0.84			
75	12	33.44	0.69	2.07	1.30	-1.35	-4.05	1.26			
85	14	21.98	0.99	4.50	0.88	-0.77	-3.52	0.58			
95	20	25.63	-1.25	-4.86	0.85	-3.53^	-13.77	0.98			
105	32	25.36	-1.24	-4.90	0.85	-2.72^	-10.73	0.70			
115	48	26.63	-1.12	-4.20	0.64	-2.96^	-11.10	0.67			
125	42	27.86	0.42	1.52	0.89	-2.32^	-8.33	0.98			
135	29	25.30	1.06	4.19	0.91	-1.86^	-7.36	0.79			
145	24	26.57	0.25	0.94	1.19	-2.32	-8.73	1.17			
175	46	27.57	-0.72	-2.62	0.56	-3.60^	-13.07	0.59			
Vol [(7)] classes	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	57	8.08	0.48^	5.88	0.17	-0.18	-2.24	0.20			
75	89	17.05	-0.26	-1.51	0.30	-2.21^	-12.95	0.30			
125	90	26.10	-0.71	-2.74	0.39	-3.32^	-12.72	0.39			
175	46	32.21	1.20	3.72	0.69	-1.97^	-6.11	0.63			
225	27	40.58	0.35	0.86	1.12	-3.30^	-8.14	1.24			
275	22	47.33	1.61	3.40	1.56	-0.68	-1.43	1.63			
325	9	56.90	-0.36	-0.63	2.28	1.21	2.13	2.18			
375	5	65.59	-1.01	-1.54	5.81	-5.84	-8.90	5.73			
425	4	84.15	-12.44	-14.79	6.92	-11.43	-13.58	4.17			
475	1	73.51	4.98	6.77	---	2.76	3.75	---			
625	3	84.19	3.48	4.14	13.42	-1.89	-2.24	12.44			
Regions	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	248	26.27	1.06^	4.04	0.29	-1.15^	-4.37	0.27			
Height[(8)]											
0 - 249	71	31.86	1.45^	4.55	0.61	-0.86	-2.69	0.53			
250-499	86	29.56	1.72^	5.83	0.61	-0.51	-1.73	0.60			
500-749	69	19.77	0.55	2.80	0.33	-1.77^	-8.95	0.32			
=/> 750	22	18.89	-0.78	-4.12	0.50	-2.33^	-12.33	0.70			
MID-	24	20.08	-0.97	-4.81	0.58	-2.88^	-14.37	0.65			
WEST	67	29.85	-3.45^	-11.55	0.56	-5.76^	-19.29	0.64			
NORTH	14	19.26	-0.66	-3.42	0.58	-1.53^	-7.97	0.49			
ALL AREA	353	26.25	0.00	0.00	0.25	-2.15^	-8.20	0.25			

1. Pine stands defined as stands where > 70% of volume from pine
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pure pine stands (table 7)
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 6 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. *25 (0-49* m^3*), 75 (50-99* m^3*),…………..625 (500-749* m^3*), 1000 (> 750* m^3*).*
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

Table A9. *Comparison of models for broadleaved stands(1), total below-ground biomass (dev.class III – V)*

Site index	N	Obser-ved (2)	Functions for pure stands (2)			Functions for mixed stands (3)			Lethonen		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	62	12.56	-0.20	-1.58	0.16	-0.33	-2.66	0.24			
8	149	20.05	-0.42	-2.09	0.25	-1.57^	-7.84	0.30			
11	96	31.94	-0.80	-2.50	0.53	-3.19^	-9.99	0.56			
14	46	41.60	-1.30	-3.12	1.03	-4.05	-9.73	1.05			
17	20	39.48	1.19	3.03	1.77	-1.12	-2.84	1.77			
20	3	52.96	7.51^	14.18	1.99	3.83	7.23	2.07			
23	2	49.28	12.09^	24.52	0.42	8.50^	17.24	0.27			
Age (6) classes	N	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	20.19	3.88	19.24	1.95	2.24	11.09	1.51			
35	21	17.95	0.49	2.76	0.72	-0.18	-0.98	0.68			
45	22	16.63	0.43	2.56	0.67	-0.44	-2.66	0.71			
55	38	27.58	-0.24	-0.89	0.68	-2.04^	-7.40	0.73			
65	56	26.46	-0.24	-0.91	0.76	-1.77^	-6.70	0.82			
75	53	22.72	-0.45	-1.97	0.53	-1.78^	-7.82	0.59			
85	48	27.90	-0.76	-2.72	0.79	-2.49^	-8.94	0.84			
95	52	23.64	-0.70	-2.97	0.46	-2.11^	-8.91	0.55			
105	41	22.68	-0.21	-0.94	0.44	-1.58^	-6.95	0.48			
115	18	27.96	-1.90	-6.80	1.10	-3.57^	-12.78	1.24			
125	8	21.53	-0.89	-4.13	1.03	-1.99	-9.26	1.32			
135	8	24.35	-1.99	-8.16	1.62	-3.38	-13.87	2.44			
145	2	65.30	-3.19	-4.89	2.96	-7.42	-11.36	1.98			
175	3	13.23	0.69	5.21	0.92	0.19	1.47	1.15			
Vol (7) classes	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	140	10.16	0.22^	2.14	0.09	0.20	1.92	0.11			
75	141	24.39	-0.31	-1.27	0.21	-2.20^	-9.03	0.21			
125	45	39.53	-1.19	-3.00	0.82	-4.24^	-10.73	0.81			
175	29	53.86	-2.94	-5.46	1.71	-6.52^	-12.11	1.69			
225	12	65.48	-0.82	-1.26	3.17	-4.95	-7.56	3.36			
275	5	69.83	4.77	6.84	4.32	0.63	0.91	4.27			
325	2	106.12	-15.99^	-15.07	0.48	-18.58^	-17.51	0.37			
375	2	118.39	-21.58	-18.23	7.72	-24.35	-20.57	7.96			
425	2	109.84	3.16	2.87	13.97	0.48	0.44	15.39			
Reg-ions	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	113	27.57	0.71	2.59	0.43	-0.93^	-3.38	0.43			
Height(8)											
0 - 249	35	50.31	1.43	2.85	1.30	-1.76	-3.50	1.32			
250-499	21	30.92	1.56	5.06	1.15	-0.56	-1.81	1.12			
500-749	20	25.86	0.60	2.33	0.69	-1.04	-4.03	0.69			
=/> 750	37	14.63	0.09	0.59	0.19	-0.56^	-3.82	0.22			
MID-	30	28.43	-1.85	-6.52	1.00	-3.58^	-12.57	1.10			
WEST	88	28.07	-1.76^	-6.28	0.55	-3.54^	-12.62	0.64			
NORTH	147	18.87	-0.18	-0.96	0.23	-1.20^	-6.35	0.26			
ALL AREA	378	24.32	-0.40	-1.65	0.22	-1.84^	-7.55	0.24			

1. Broadleaved stands defined as stands where > 70% of volume from broadleaved tree species.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for broadleaved stands (table 8)
4. The functions for mixed stands (table 9)
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)……….175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. Significant differences, 5% level.

Table A10. *Comparison of models for mixed stands dominated by conifer species* [1]*, total below-ground biomass (dev.class III – V)*

Site index	N	Observed [2]	Functions for pure stands [3]			Functions for mixed stands [4]			Lethonen [5]		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	25	19.64	-2.91^	-14.80	0.79	-2.35^	-11.98	0.82			
8	69	24.65	-2.39^	-9.71	0.47	-1.41^	-5.71	0.36			
11	68	31.99	-1.78^	-5.56	0.52	-0.26	-0.82	0.41			
14	67	34.46	0.63	1.82	0.59	2.21^	6.40	0.42			
17	16	46.61	2.54	5.44	2.16	5.29^	11.35	1.85			
20	7	44.48	4.96	11.15	3.12	6.97	15.68	3.38			
23	3	61.60	2.07	3.35	6.62	12.00	19.49	7.98			
Age [6] classes	**N**	**Observed**	**Diff**	**Rel d %**	**Std Err**	**Diff**	**Rel d %**	**Std Err**	**Diff**	**Rel d %**	**Std Err**
25	8	33.60	-4.34	-12.90	2.11	-1.76	-5.23	1.63			
35	23	23.96	0.29	1.21	0.82	1.15	4.79	0.81			
45	29	29.78	0.01	0.04	0.88	2.03	6.80	1.12			
55	19	34.70	3.77^	10.88	1.69	4.66^	13.44	1.39			
65	23	31.12	-1.03	-3.31	1.18	0.86	2.75	1.06			
75	17	32.59	0.44	1.35	1.29	1.90	5.84	1.18			
85	20	30.37	-0.85	-2.81	1.27	0.68	2.23	0.95			
95	14	27.81	-0.98	-3.53	1.52	1.04	3.76	1.08			
105	15	30.29	-2.71^	-8.95	0.66	-1.12	-3.69	0.64			
115	17	25.10	-2.00	-7.99	1.23	-1.29	-5.13	0.90			
125	24	34.51	-2.00^	-5.80	0.86	-0.39	-1.12	0.76			
135	19	31.94	-3.97^	-12.43	1.09	-2.89^	-9.06	1.04			
145	17	32.11	-2.90^	-9.04	0.82	-1.89^	-5.88	0.88			
175	10	40.79	-0.24	-0.59	0.80	1.73	4.23	1.08			
Vol [7] classes	**N**	**Observed**	**Diff**	**Rel d %**	**Std Err**	**Diff**	**Rel d %**	**Std Err**	**Diff**	**Rel d %**	**Std Err**
25	37	10.31	-0.60	-5.79	0.31	0.02	0.19	0.28			
75	67	20.16	-1.31^	-6.49	0.40	-0.63	-3.15	0.34			
125	54	29.72	-2.26^	-7.60	0.66	-1.33^	-4.48	0.59			
175	41	37.99	-1.14	-2.99	0.87	0.25	0.65	0.58			
225	20	46.39	0.01	0.02	1.59	0.97	2.09	1.22			
275	21	52.10	0.93	1.78	1.77	4.54^	8.71	1.16			
325	6	62.76	0.82	1.31	4.46	8.40**?**	13.39	3.46			
375	6	69.09	1.15	1.66	2.31	5.93**?**	8.58	2.44			
425	2	81.61	-4.00	-4.90	4.10	9.66	11.84	11.99			
475	1	77.01	14.51	18.84	---	23.03	29.90	---			
Regions	**N**	**Observed**	**Diff**	**Rel d %**	**Std Err**	**Diff**	**Rel d %**	**Std Err**	**Diff**	**Rel d %**	**Std Err**
SOUTH	187	32.03	-0.05	-0.16	0.38	1.61^	5.03	0.36			
Height [8]											
0 - 249	63	40.18	0.54	1.35	0.79	4.12^	10.26	0.75			
250-499	60	32.26	1.09	3.39	0.62	1.82^	5.63	0.43			
500-749	45	24.19	-1.01	-4.19	0.52	-0.26	-1.06	0.42			
=/> 750	19	23.56	-3.10^	-13.18	0.89	-2.60^	-11.02	0.95			
MID-	37	30.30	-3.09^	-10.20	0.72	-2.53^	-8.36	0.45			
WEST	19	25.19	-3.68^	-14.59	1.24	-2.31^	-9.18	0.90			
NORTH	12	25.23	-3.54^	-14.02	1.13	-2.18	-8.65	1.00			
ALL AREA	255	30.91	-0.94^	-3.05	0.33	0.52	1.70	0.30			

1. Mixed stands defined as stands where < 70% of volume from main tree species. Only mixed stands dominated by conifer species are included.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pine stands used when pine dominates (table 7) or the functions for spruce (table 6) when spruce is the dominant species in the stand.
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 6 and 7 in Lethonen et al.2004 (Same procedure as described above at point 3. Viken 1).
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: $m^3 ha^{-1}$. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. Significant differences, 5% level.

Table A11. *Comparison of models for spruce stands(1), below-ground biomass for bioenergy (dev. class III – V)*

Site index	N	Obser-ved (2)	Functions for pure stands (3)			Functions for mixed stands (4)			Lethonen (5)		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	38	22.72	-2.89^	-12.70	0.77	-3.30^	-14.54	0.77	-7.13^	-31.38	0.82
8	83	28.92	-1.69^	-5.84	0.50	-2.47^	-8.55	0.49	-5.72^	-19.78	0.50
11	83	31.32	0.23	0.72	0.47	-0.57	-1.83	0.46	-2.76^	-8.80	0.48
14	62	36.20	1.44^	3.99	0.69	0.30	0.83	0.66	-0.39	-1.07	0.85
17	65	42.68	1.96^	4.60	0.72	1.48^	3.47	0.73	1.68	3.94	0.99
20	50	53.29	0.42	0.80	1.17	0.20	0.38	1.14	2.17	4.08	1.12
23	21	66.00	2.25	3.41	1.17	4.27^	6.47	1.68	9.67^	14.65	2.12
26	2	53.11	-3.07	-5.79	3.32	-1.91	-3.60	0.21	-1.59	-2.99	0.58
Age (6) classes	N	Obser-ved	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	13	20.60	1.96^	9.54	0.57	0.26	1.27	0.74	-1.27	-6.17	0.65
35	47	25.57	1.01	3.96	0.62	-0.38	-1.50	0.63	-1.92^	-7.52	0.60
45	44	43.16	0.36	0.84	1.12	-0.52	-1.19	1.06	0.49	1.15	1.39
55	48	50.53	0.32	0.63	1.02	1.16	2.30	1.12	2.33	4.61	1.30
65	32	46.48	2.54^	5.45	0.84	2.25^	4.84	0.96	2.98^	6.41	1.24
75	23	37.68	0.55	1.47	1.17	0.76	2.01	1.10	-1.59	-4.23	1.19
85	11	46.31	1.81	3.90	1.18	1.85	4.00	0.91	2.32	5.00	2.08
95	12	29.30	1.23	4.19	0.89	0.38	1.30	0.96	-2.26	-7.71	1.14
105	27	36.16	1.32	3.66	0.83	1.18	3.27	1.07	0.72	1.99	1.73
115	38	34.81	-0.38	-1.09	0.81	-0.76	-2.18	0.76	-3.04^	-8.74	0.93
125	23	32.50	-2.14	-6.58	1.24	-3.08^	-9.48	1.13	-5.97^	-18.37	1.25
135	32	36.07	-0.94	-2.61	1.09	-1.78	-4.93	1.08	-3.78^	-10.48	1.44
145	24	34.18	-2.94^	-8.61	1.27	-3.35^	-9.79	1.16	-6.24^	-18.26	1.44
175	30	33.69	-2.17^	-6.45	0.87	-3.27^	-9.69	0.88	-5.46^	-16.20	1.09
Vol (7) classes	**N**	Obser-ved	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	32	7.68	1.46^	19.06	0.20	1.21^	15.74	0.17	-1.61^	-20.98	0.24
75	87	17.82	0.29	1.62	0.31	-0.76^	-4.24	0.29	-4.02^	-22.56	0.34
125	64	27.17	-0.80	-2.94	0.56	-1.87^	-6.90	0.54	-5.24^	-19.30	0.57
175	61	34.34	-0.17	-0.49	0.71	-1.58^	-4.61	0.63	-3.99^	-11.61	0.74
225	37	43.69	-1.63	-3.72	1.02	-2.67^	-6.12	0.91	-4.27^	-9.78	1.03
275	33	49.14	0.16	0.33	1.21	-0.71	-1.44	1.19	-0.90	-1.83	1.23
325	31	53.76	2.27^	4.23	0.96	2.59^	4.81	0.93	3.00^	5.58	0.95
375	16	61.71	1.25	2.03	2.64	0.86	1.40	2.66	3.97	6.43	2.66
425	15	69.98	-1.19	-1.70	2.39	-0.60	-0.86	2.19	3.62	5.17	2.41
475	6	75.02	-0.45	-0.60	4.21	2.80	3.73	5.77	6.45	8.59	4.40
625	20	88.80	1.54	1.74	1.70	5.25^	5.91	1.99	15.50^	17.46	1.90
100	2	128.66	-14.50	-11.27	9.77	-11.29	-8.77	9.44	11.68	9.08	7.82
Reg-ions	**N**	Obser-ved	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	274	36.61	1.27^	3.47	0.32	0.74^	2.01	0.34	-0.41	-1.12	0.47
Height(8)											
0 - 249	58	42.76	5.13^	12.00	0.57	4.92^	11.50	0.72	5.58^	13.06	1.14
250-499	75	40.25	2.75^	6.84	0.55	2.38^	5.90	0.56	2.06^	5.12	0.79
500-749	102	32.42	0.03	0.10	0.37	-0.64	-1.96	0.38	-2.64^	-8.14	0.47
=/> 750	39	31.80	-3.87^	-12.18	0.83	-4.80^	-15.10	0.82	-7.91^	-24.88	0.85
MID-	77	31.19	-1.49^	-4.76	0.56	-2.09^	-6.69	0.50	-4.46	-14.29	0.57
WEST	29	65.36	-5.42^	-8.30	1.52	-5.47^	-8.37	1.49	-0.49	-0.75	1.95
NORTH	24	31.27	-2.10^	-6.71	0.86	-2.89^	-9.24	0.81	-5.02	-16.05	0.83
ALL AREA	404	37.15	0.10	0.26	0.28	-0.43	-1.16	0.29	-1.47	-3.95	0.38

1. Spruce stands defined as stands where > 70% of volume from spruce
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pure spruce stands (table 6)
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 7 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

***Table A12. .** Comparison of models for pine stands (1), below-ground biomass for bioenergy (dev. class III – V)*

Site index	N	Observed (2)	Functions for pure stands (3)			Functions for mixed stands (4)			Lethonen (5)		
			Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
6	64	17.37	-1.62^	-9.30	0.38	-3.60^	-20.75	0.46	-5.79^	-33.35	0.42
8	148	21.82	-0.37	-1.69	0.34	-2.62^	-12.02	0.35	-3.90^	-17.90	0.32
11	83	25.90	0.24	0.91	0.42	-1.59^	-6.13	0.38	-2.31^	-8.92	0.43
14	37	32.82	2.63^	8.01	0.99	1.31	4.00	0.91	2.39	7.27	1.23
17	20	34.49	2.12	6.16	1.49	1.01	2.92	1.04	2.60	7.55	1.47
20	1	32.40	5.56	17.15	---	5.96	18.39	---	6.23	19.22	---
Age (6) classes	N	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
35	9	14.01	0.48	3.45	0.62	-0.30	-2.14	0.58	-2.34^	-16.72	0.76
45	15	19.16	1.28	6.68	0.56	0.12	0.64	0.49	-0.92	-4.80	0.81
55	35	25.50	1.48	5.79	1.02	-0.35	-1.37	0.90	-0.56	-2.20	1.11
65	27	22.71	0.83	3.64	0.76	-0.54	-2.38	0.76	-1.14	-5.02	0.91
75	12	30.32	0.84	2.76	1.24	-0.90	-2.96	1.17	0.72	2.36	2.13
85	14	19.75	1.09	5.52	0.77	-0.51	-2.57	0.52	-1.82	-9.21	0.90
95	20	23.36	-1.23	-5.28	0.82	-3.23^	-13.82	0.93	-4.19^	-17.92	0.66
105	32	23.03	-1.13	-4.91	0.77	-2.51^	-10.89	0.66	-4.04^	-17.55	0.65
115	48	24.22	-1.07	-4.40	0.60	-2.76^	-11.39	0.63	-4.29^	-17.70	0.63
125	42	25.40	0.29	1.12	0.83	-2.16^	-8.50	0.90	-3.00^	-11.82	0.83
135	29	23.20	0.75	3.22	0.84	-1.77^	-7.64	0.75	-2.19	-9.43	1.36
145	24	24.30	0.06	0.26	1.11	-2.23	-9.17	1.10	-2.86^	-11.77	1.19
175	46	25.29	-0.93	-3.68	0.54	-3.51^	-13.86	0.57	-4.83^	-19.11	0.58
Vol (7) classes	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
25	57	7.28	0.40^	5.46	0.16	-0.20	-2.76	0.19	-2.33^	-31.99	0.21
75	89	15.43	-0.28	-1.80	0.29	-2.01^	-13.05	0.29	-4.17^	-27.01	0.32
125	90	23.73	-0.71	-3.01	0.37	-3.02^	-12.74	0.37	-4.54^	-19.11	0.40
175	46	29.28	1.10	3.75	0.65	-1.72^	-5.88	0.60	-2.28^	-7.80	0.69
225	27	36.99	0.32	0.87	1.08	-2.90^	-7.84	1.17	-1.79	-4.83	1.19
275	22	42.80	1.91	4.45	1.48	-0.26	-0.62	1.52	1.52	3.56	1.61
325	9	51.40	0.33	0.64	2.17	1.18	2.29	2.10	1.92	3.73	2.28
375	5	60.33	-1.21	-2.01	5.55	-5.29	-8.77	5.47	1.35	2.24	5.47
425	4	77.00	-11.25	-14.61	6.00	-10.54	-13.69	3.97	-5.55	-7.20	5.96
475	1	67.03	5.05	7.53	---	3.45	5.14	---	14.30	21.33	---
625	3	77.47	3.07	3.96	12.33	-1.06	-1.36	11.56	14.18	18.30	12.72
Regions	**N**	Observed	Diff	Rel d %	S Err	Diff	Rel d %	S Err	Diff	Rel d %	S Err
SOUTH	248	23.83	1.01^	4.23	0.27	-0.98^	-4.13	0.26	-1.77^	-7.43	0.32
Height (8)											
0 - 249	71	28.85	1.46^	5.07	0.57	-0.63	-2.17	0.51	-0.88	-3.03	0.63
250-499	86	26.82	1.65^	6.15	0.57	-0.40	-1.49	0.54	-0.70	-2.62	0.65
500-749	69	17.89	0.51	2.88	0.31	-1.52^	-8.49	0.30	-2.90	-16.22	0.37
=/> 750	22	17.35	-0.97	-5.60	0.50	-2.39^	-13.78	0.68	-4.54	-26.14	0.59
MID-	24	18.19	-0.90	-4.96	0.55	-2.65^	-14.54	0.62	-4.55^	-25.03	0.54
WEST	67	27.27	-3.28^	-12.02	0.53	-5.28^	-19.38	0.60	-5.98^	-21.94	0.69
NORTH	14	17.29	-0.46	-2.63	0.53	-1.29^	-7.49	0.45	-3.63^	-20.97	0.76
ALL AREA	353	26.25	0.00	0.00	0.25	-2.15^	-8.20	0.25	-2.83	-11.86	0.28

1. Pine stands defined as stands where > 70% of volume from pine
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pure pine stands (table 7)
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 6 in Lethonen et al.2004.
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

***Table A13. .** Comparison of models for broadleaved stands* [(1)]*, below-ground biomass for bioenergy (dev. class III – V)*

Site index	N	Observed [(2)]	Functions for pure stands [(3)]			Functions for mixed stands [(4)]			Lethonen		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	62	10.92	-0.17	-1.59	0.14	-0.40	-3.71	0.21			
8	149	17.45	-0.38	-2.20	0.22	-1.54^	-8.81	0.26			
11	96	27.78	-0.72	-2.60	0.47	-3.02^	-10.86	0.50			
14	46	36.13	-1.10	-3.05	0.91	-3.83^	-10.59	0.93			
17	20	34.25	1.10	3.20	1.56	-1.28	-3.72	1.57			
20	3	45.92	6.63^	14.43	1.78	2.79	6.07	1.81			
23	2	42.32	11.00^	26.00	0.24	7.28^	17.21	0.19			
Age [(6)] classes	N	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	17.44	3.48	19.93	1.75	1.84	10.57	1.32			
35	21	15.53	0.50	3.19	0.65	-0.26	-1.69	0.59			
45	22	14.44	0.38	2.65	0.59	-0.51	-3.51	0.63			
55	38	23.95	-0.19	-0.79	0.60	-1.98^	-8.27	0.65			
65	56	23.02	-0.23	-0.99	0.67	-1.76^	-7.65	0.72			
75	53	19.76	-0.40	-2.03	0.46	-1.74^	-8.80	0.52			
85	48	24.28	-0.69	-2.82	0.69	-2.40^	-9.88	0.74			
95	52	20.58	-0.64	-3.10	0.40	-2.03^	-9.87	0.49			
105	41	19.74	-0.20	-1.03	0.39	-1.56^	-7.88	0.44			
115	18	24.33	-1.67	-6.88	0.96	-3.33^	-13.68	1.10			
125	8	18.70	-0.76	-4.04	0.90	-1.89	-10.12	1.19			
135	8	21.23	-1.79	-8.43	1.47	-3.15	-14.86	2.21			
145	2	56.61	-2.64	-4.66	2.76	-6.93	-12.24	1.68			
175	3	11.50	0.60	5.21	0.81	0.05	0.41	1.02			
Vol [(7)] classes	**N**	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	140	8.84	0.19^	2.14	0.07	0.07	0.84	0.10			
75	141	21.21	-0.28	-1.34	0.18	-2.10^	-9.90	0.18			
125	45	34.36	-1.03	-3.00	0.72	-3.97^	-11.54	0.71			
175	29	46.83	-2.57	-5.49	1.50	-6.09^	-13.01	1.47			
225	12	57.02	-0.82	-1.44	2.80	-4.89	-8.58	2.95			
275	5	60.52	4.31	7.13	3.81	-0.03	-0.05	3.73			
325	2	92.35	-14.02^	-15.18	0.43	-17.17^	-18.59	0.37			
375	2	103.00	-18.87	-18.32	6.72	-22.14	-21.49	6.89			
425	2	95.49	2.71	2.84	12.13	-0.69	-0.72	13.44			
Regions	**N**	Observed	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	113	23.95	0.64	2.68	0.38	-1.03^	-4.32	0.38			
Height [(8)]											
0 - 249	35	43.73	1.24	2.84	1.15	-1.97	-4.51	1.16			
250-499	21	26.74	1.49	5.58	1.03	-0.65	-2.43	1.00			
500-749	20	22.43	0.56	2.51	0.61	-1.12	-5.00	0.61			
=/> 750	37	12.73	0.07	0.52	0.16	-0.61^	-4.80	0.20			
MID-	30	24.73	-1.63	-6.59	0.87	-3.34^	-13.51	0.99			
WEST	88	24.43	-1.57^	-6.42	0.48	-3.30^	-13.50	0.57			
NORTH	147	16.41	-0.17	-1.02	0.20	-1.20^	-7.29	0.23			
ALL AREA	378	21.15	-0.36	-1.69	0.19	-1.79^	-8.48	0.22	-6.98^	-13.74	0.35

1. Broadleaved stands defined as stands where > 70% of volume from broadleaved tree species.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for broadleaved stands (table 8)
4. The functions for mixed stands (table 9)
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)……….175 (> 150 years).
7. Volume classes: m^3ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. *Significant differences, 5% level.*

***Table A14. .** Comparison of models for mixed stands dominated by conifer species [(1)], below-ground biomass for bioenergy (dev. class III – V)*

Site index	N	Obser-ved [(2)]	Functions for pure stands [(3)]			Functions for mixed stands [(4)]			Lethonen [(5)]		
			Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
6	25	17.24	-2.61^	-15.13	0.72	-2.28^	-13.23	0.75	-6.65^	-38.57	0.80
8	69	21.70	-2.02^	-9.31	0.40	-1.44^	-6.66	0.32	-5.79^	-26.68	0.40
11	68	27.95	-1.45^	-5.19	0.45	-0.29	-1.04	0.38	-4.54^	-16.25	0.47
14	67	29.98	0.86	2.86	0.48	2.01^	6.70	0.37	-1.54^	-5.12	0.52
17	16	40.41	2.24	5.55	1.83	4.64^	11.49	1.66	1.26	3.11	1.81
20	7	37.99	4.36	11.48	2.53	6.43	16.93	2.86	3.93	10.34	3.79
23	3	52.68	1.92	3.65	5.89	10.36	19.67	7.03	3.04	5.78	6.94
Age [(6)] classes	N	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	8	28.39	-3.31	-11.66	1.92	-1.14	-4.01	1.44	-6.43^	-22.65	1.85
35	23	20.47	0.55	2.70	0.71	1.23	6.03	0.74	-2.36^	-11.52	0.71
45	29	25.51	0.48	1.89	0.74	2.09^	8.19	0.96	-2.18^	-8.56	0.91
55	19	30.23	3.46^	11.43	1.36	4.16^	13.75	1.23	1.35	4.48	1.77
65	23	27.21	-0.81	-2.98	1.03	0.67	2.46	0.99	-3.50^	-12.88	1.14
75	17	28.38	0.48	1.68	1.12	1.64	5.79	1.07	-2.35	-8.28	1.34
85	20	26.68	-0.78	-2.93	1.05	0.39	1.45	0.83	-3.67^	-13.77	1.13
95	14	24.44	-0.78	-3.21	1.25	0.71	2.89	0.95	-3.74^	-15.31	1.24
105	15	26.53	-2.18^	-8.23	0.57	-1.09	-4.09	0.57	-5.28^	-19.89	0.66
115	17	22.05	-1.70	-7.73	1.04	-1.30	-5.88	0.81	-5.48^	-24.85	1.01
125	24	30.41	-1.69^	-5.57	0.75	-0.62	-2.05	0.69	-4.45^	-14.64	1.00
135	19	28.12	-3.49^	-12.42	0.93	-2.84^	-10.09	0.92	-7.39^	-26.26	0.95
145	17	28.13	-2.66^	-9.47	0.73	-1.91^	-6.78	0.81	-6.10^	-21.68	0.96
175	10	36.32	-0.41	-1.12	0.78	0.93	2.55	0.98	-2.96^	-8.16	0.77
Vol [(7)] classes	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
25	37	9.00	-0.47	-5.26	0.29	-0.05	-0.56	0.27	-3.41^	-37.92	0.34
75	67	17.41	-0.97^	-5.58	0.35	-0.55	-3.13	0.32	-4.97^	-28.56	0.37
125	54	26.01	-1.81^	-6.96	0.59	-1.27^	-4.89	0.54	-5.75^	-22.10	0.63
175	41	33.19	-0.82	-2.47	0.73	0.18	0.55	0.53	-4.15^	-12.51	0.75
225	20	40.56	-0.09	-0.23	1.36	0.73	1.79	1.13	-2.35	-5.80	1.32
275	21	45.70	1.15	2.51	1.43	3.86^	8.45	1.00	0.53	1.16	1.48
325	6	54.15	0.95	1.76	3.80	7.35	13.58	3.24	1.91	3.53	3.67
375	6	60.57	0.39	0.64	2.01	4.79	7.91	2.28	2.59	4.28	2.18
425	2	71.88	-3.59	-5.00	3.67	7.51	10.45	10.95	1.03	1.43	5.14
475	1	66.53	12.17	18.30	---	20.31	30.54	---	20.90	31.41	---
Reg-ions	**N**	Obser-ved	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err	Diff	Rel d %	Std Err
SOUTH	187	27.98	0.12	0.42	0.32	1.33^	4.77	0.41	-2.63^	-9.40	0.38
Height[(8)]											
0 - 249	63	35.23	0.70	2.00	0.66	3.43^	9.73	0.68	-0.92	-2.60	0.78
250-499	60	28.05	1.25^	4.46	0.50	1.72^	6.12	0.38	-1.71^	-6.11	0.55
500-749	45	21.17	-0.83	-3.92	0.44	-0.36	-1.69	0.39	-4.24^	-20.03	0.48
=/> 750	19	20.51	-2.91^	-14.18	0.81	-2.50^	-12.18	0.85	-7.02^	-34.25	0.92
MID-	37	26.24	-2.76^	-10.54	0.62	-2.26^	-8.60	0.97	-6.38^	-24.31	0.68
WEST	19	22.43	-3.37^	-15.04	1.08	-2.37^	-10.58	0.32	-6.46^	-28.80	1.09
NORTH	12	21.23	-2.47^	-11.63	0.96	-1.43	-6.76	0.85	-6.26^	-29.46	1.03
ALL AREA	255	26.97	-0.70^	-2.60	0.28	0.39	1.44	0.27	-3.65^	-13.52	0.32

1. Mixed stands defined as stands where < 70% of volume from main tree species. Only mixed stands dominated by conifer species are included.
2. Observed: Mean (dry weight in Mg - 1000kg) calculated from Marklund's and Petersson & Ståhl's functions.
3. The functions for pine stands used when pine dominates (table 7) or the functions for spruce (table 6) when spruce is the dominant species in the stand.
4. The functions for mixed stands (table 9)
5. Lethonen = Finnish functions from table 6 and 7 in Lethonen et al.2004 (Same procedure as described above at point 3).
6. Age classes: Defined as stand age: 25 (20-29 years), 35 (30-39 years)………175 (> 150 years).
7. Volume classes: m^{3}ha^{-1}. 25 (0-49 m^3), 75 (50-99 m^3),…………..625 (500-749 m^3), 1000 (> 750 m^3).
8. Regions of Norway. The southeast also divided in classes of elevation
^. Significant differences, 5% level.

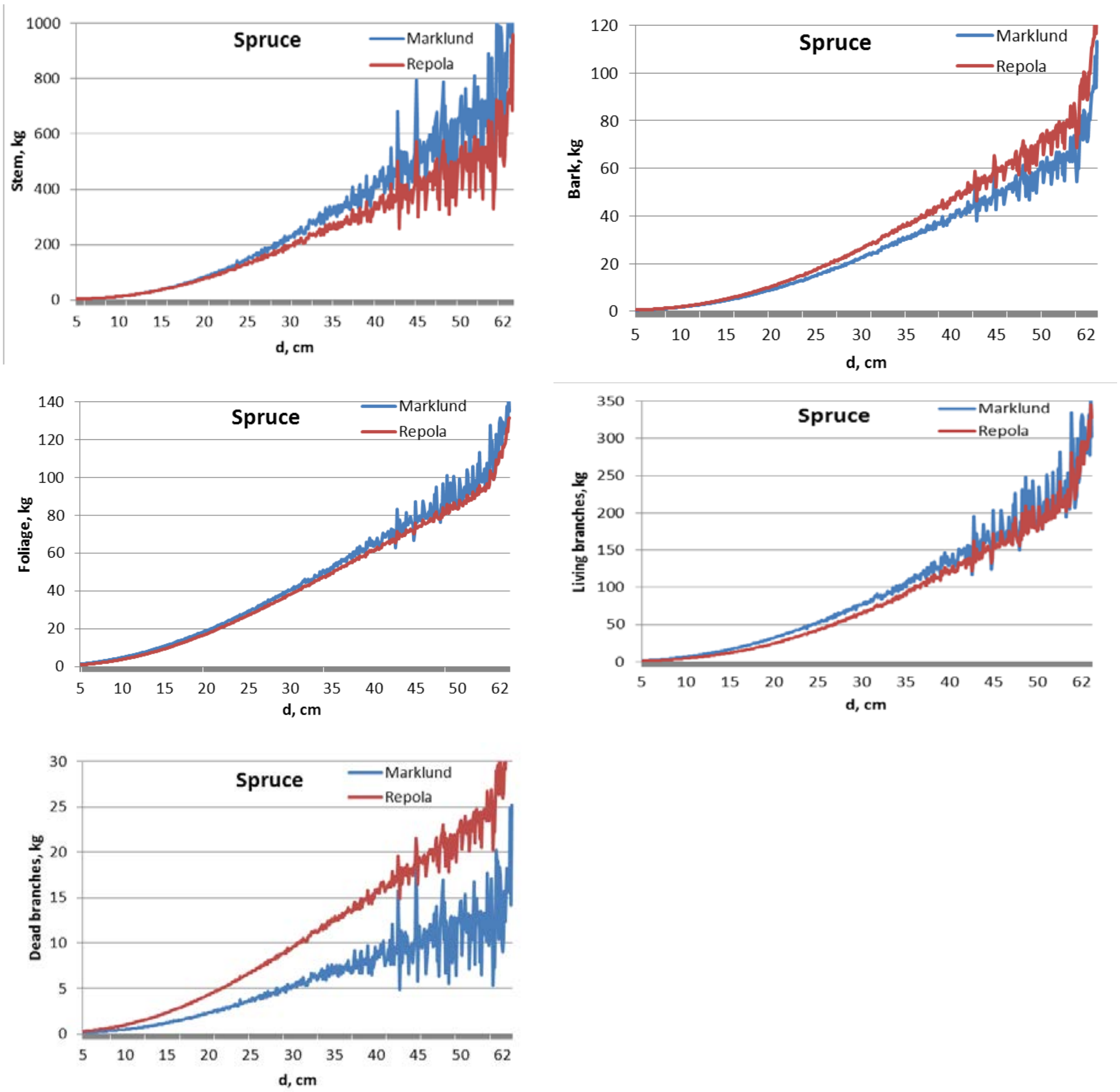

Figure A1. Calculated biomass for different parts of the tree for spruce in the NFI data using functions from Marklund and Repola.

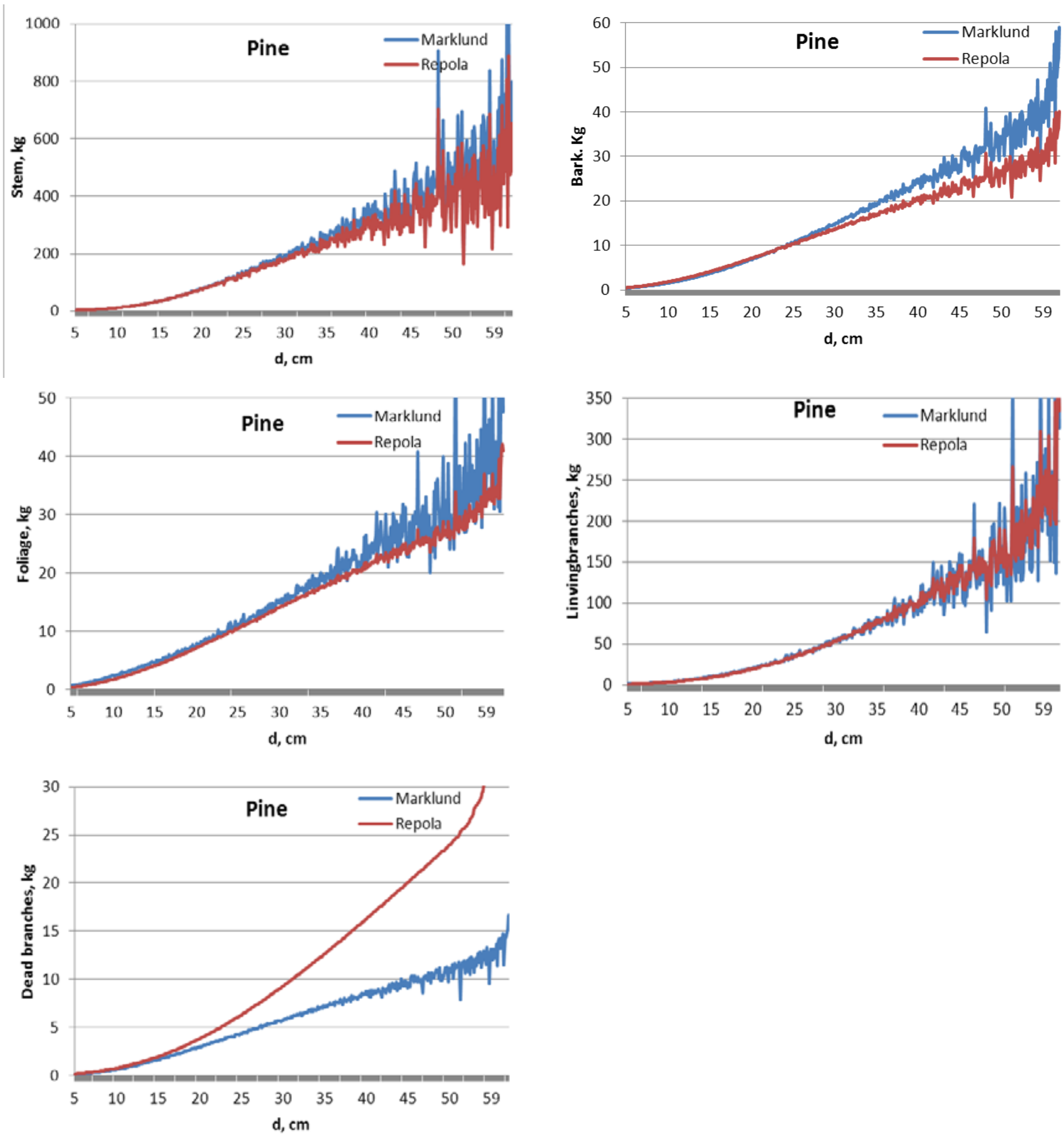

Figure A2. Calculated biomass for different parts of the tree for pine in the NFI data using functions from Marklund and Repola.

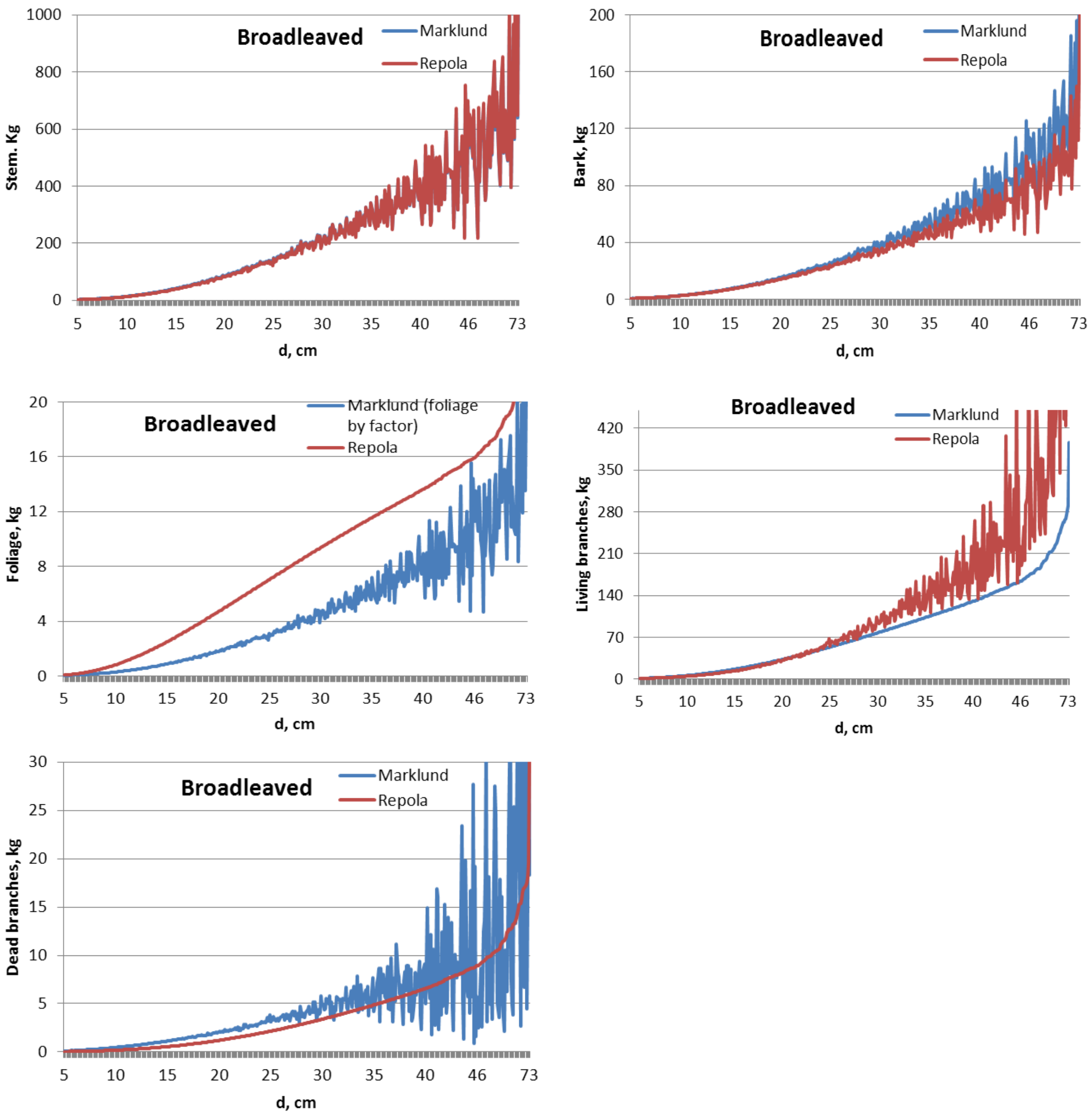

Figure A3. Calculated biomass for different parts of the tree for broadleaved species in the NFI data using functions from Marklund and Repola. Foliage from "Marklund" estimating by using a constant factor of 2,2% multiplied by the stem volume for the actual tree.