

Appendix 1

Calculation of ΔB of the stand based on single tree measurements of the 2nd and the 3rd NFI in Germany

1. Obtaining diameter at breast height (dbh) and height for all sample trees on a NFI plot

In German NFI sampling, dbh of all trees in the angle-count sampling with basal area factor 4 (ACS₄) is measured, whereas height is only measured for a subsample of trees (main storey: two trees of the dominant species group and one tree of each remaining species group, under storey and top storey: one tree of each species group) (BMELV, 2011). Heights that are not measured are derived from species-specific uniform height-diameter curves (Riedel *et al.*, 2017).

There are trees that were included in ACS₄ in NFI 3 but had not been thick enough to be included in NFI 2. Other trees were measured for the NFI 2 but were missing in the NFI 3 due to harvest, thinning or mortality. Diameter at breast height and height of these trees were predicted for the middle of the period between NFI 2 and NFI 3 (e.g. Jenkins *et al.*, 2001; Dahm, 2006) using the function of Sloboda (Riedel *et al.*, 2017).

2. Estimation of single tree above-ground wood biomass

Species-specific functions by Zell (2008) were used for the calculation of total single tree above-ground wood biomass (kg) based on dbh (cm) and height (m) measurements or estimations respectively:

$$biomass = a * dbh^b * height^c$$

Coefficients a, b and c for each species present in the NFI data are detailed in Table A1.

Table A1. Coefficients (a, b and c) for each species group in the biomass functions developed by Zell (2008). Species were assigned to the species groups according to Klein & Schulz (2012)

species group	a	b	c	species
spruce	0.0673	1.9378	0.6382	<i>Picea abies</i> , <i>Picea spec.</i> , all other conifers not specified in NFI data
pine	0.058	2.034	0.637	<i>Pinus sylvestris</i> , <i>Pinus mugo</i> , <i>Pinus nigra</i> , <i>Pinus strobus</i> , <i>Pinus spec.</i>
fir	0.04	2.06631	0.67061	<i>Abies alba</i> , <i>Abies grandis</i> , <i>Abies spec.</i> , <i>Pseudotsuga menziesii</i> , <i>Taxus baccata</i>
larch	0.079	1.857	0.736	<i>Larix decidua</i> , <i>Larix kaempferi</i>
beech	0.0365	2.1082	0.7696	<i>Fagus sylvatica</i> , <i>Acer platanoides</i> , <i>Acer campestre</i> , <i>Acer pseudoplatanus</i> , <i>Aesculus hippocastanum</i> , <i>Carpinus betulus</i> , <i>Castanea sativa</i> , <i>Juglans spec.</i> , <i>Prunus avium</i> , <i>Prunus padus</i> , <i>Prunus serotina</i> , <i>Sorbus spec.</i> , <i>Tilia spec.</i> , other deciduous trees with high life expectancy
oak	0.04428151	2.096	0.712	<i>Quercus petraea</i> , <i>Quercus robur</i> , <i>Quercus rubra</i> , <i>Fraxinus excelsior</i> , <i>Robinia pseudoacacia</i> , <i>Ulmus spec.</i>
alder	0.018	2.069	0.9	<i>Alnus glutinosa</i> , <i>Alnus incana</i> , <i>Alnus spec.</i>
birch	0.060	1.971	0.7	<i>Betula pendula</i> , <i>Betula pubescens</i> , <i>Malus sylvestris</i> , <i>Populus alba</i> , <i>Populus nigra</i> , <i>Populus tremula</i> , <i>Populus x canescens</i> , <i>Populus trichocarpa x maximoviczii</i> , <i>Pyrus communis</i> , <i>Salix spec.</i> , <i>Sorbus aria</i> , <i>Sorbus aucuparia</i> , <i>Sorbus torminalis</i> , other deciduous trees with low life expectancy

3. Calculation of the biomass increment of single trees

The biomass increment in kg yr^{-1} of each tree was calculated:

$$\text{biomass increment per year} = \frac{\text{biomass}_{\text{NFI3}} - \text{biomass}_{\text{NFI2}}}{\text{year}_{\text{NFI3}} - \text{year}_{\text{NFI2}}}$$

In general:

$$\text{year}_{\text{NFI3}} = 2012$$

$$\text{year}_{\text{NFI2}} = 2002$$

Special case: ingrowth (trees that were included in the ACS₄ in NFI 3 but had not been thick enough to be included in NFI 2)

$$\text{year}_{\text{NFI3}} = 2012$$

$$\text{year}_{\text{NFI2}} = 2007$$

Special case: missing trees due to harvest, thinning or mortality (trees that were measured for the NFI 2 but were missing in the NFI 3)

$$\text{year}_{\text{NFI3}} = 2007$$

$$\text{year}_{\text{NFI2}} = 2002$$

4. Estimation of the biomass increment of the stand in $\text{kg ha}^{-1} \text{yr}^{-1}$

One NFI plot represents a stand of one ha. Each sample tree in ACS₄ represents a certain number of trees per ha (N_{ha}) according to its basal area (BA):

$$N_{\text{ha}} = \frac{4}{BA}$$

In order to obtain increment per ha the increment of the individual tree is multiplied by its N_{ha} . N_{ha} depends on the basal area of the tree, i.e. N_{ha} is higher at the first measurement than at the second measurement as the basal area of the trees increases. Therefore, for scaling up to one ha we used the mean of the stem number per ha of the 2nd and 3rd NFI. (Standard

evaluation of the German NFI uses N_{ha} of the second measurement to estimate growth values on ha basis (Dahm 2006)). For consistency with the general NFI evaluation we had used N_{ha} of the 3rd NFI (i.e. the second measurement) at first. However, our validation on an independent dataset of experimental plots showed that this would result in a systematic underestimation of ΔB (see also Eastaugh & Hasenauer, 2013). Therefore, we decided to use the mean of the stem number per ha of the 2nd and 3rd NFI.)

$$\text{biomass increment per year and ha} = \text{biomass increment per year} * N_{ha}$$

Biomass increment of the stand in $\text{kg ha}^{-1} \text{ yr}^{-1}$ is then derived by summing up biomass increment per year and ha of all trees on the NFI plot:

$$\Delta B = \sum_{i=1}^n \text{biomass increment per year and ha}$$

with n being the number of sample trees on the plot.

References

- BMELV, 2011. Aufnahmeanweisung für die dritte Bundeswaldinventur (BWI³) (2011-2012). Institut für Waldökologie und Waldinventuren im Johann Heinrich von Thünen-Institut. Bonn.
- Dahm S, 2006. Auswertungsalgorithmen für die zweite Bundeswaldinventur. Bundesforschungsanstalt für Forst- und Holzwirtschaft Hamburg, Institut für Waldökologie und Waldinventuren. Eberswalde.
- Eastaugh CS, Hasenauer H, 2013. Biases in Volume Increment Estimates Derived from Successive Angle Count Sampling. *Forest Sci* 59 (1): 1–14.
- Jenkins JC, Birdsey RA, Pan Y, 2001. Biomass and NPP estimation for the mid-Atlantic Region (USA) using plot-level forest inventory data. *Ecol Appl* 11 (4).

Klein D, Schulz C, 2012. Die Kohlenstoffbilanz der Bayerischen Forst- und Holzwirtschaft, Abschlussbericht 09/2012. Bayerische Landesanstalt für Wald und Forstwirtschaft, Freising.

Riedel T, Hennig P, Kroiher F, Polley H, Schmitz F, Schwitzgebel F, 2017. Die dritte Bundeswaldinventur (BWI 2012). Inventur- und Auswertemethoden. Johann Heinrich von Thünen-Institut.

Zell J, 2008. Methoden für die Ermittlung, Modellierung und Prognose der Kohlenstoffspeicherung in Wäldern auf Grundlage permanenter Großrauminventuren. Albert-Ludwigs-Universität, Freiburg im Breisgau.