Forest Growth Model 4C: Validation of the Grading Module Using Data and Models from Growth and Yield Science

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Background

The Model 4C (FORESt Ecosystems in a changing Environment), (Lasch et al, 2002), includes a grading module, which delivers a classification of timber yield and standing volume into different timber grades (stem wood, log, industrial wood, fuel wood). The calculated timber grades together with a monetary evaluation are a prerequisite for the application of a wood product model and multi criteria analyses.

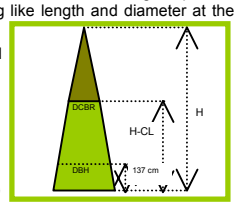
Our study aims at the analysis and validation of the 4C grading algorithm using stem taper functions and the program "Holzernte 6.0". We compared the stem volume of single trees as well as the timber grades of total stands calculated by the grading algorithm.

Model 4C

The grading module of 4C classifies the stems of a forest stand according to species-specific parameters of timber grades in Brandenburg like length and diameter at the top and the middle of the log.

Calculations of different log characteristics are based on the stem geometry used in 4C, characterized by:

- diameter at breast height (137 cm): DBH
- diameter at crown base: DCRB
- crown length: CL
- composition of frustum (from tree base to crown base) and conus (above crown base)



Data

We selected two sites from the long-term monitoring plots in the Federal State of Brandenburg:

- Scots pine stand Chorin, data for 1971(58 years old), 1990 (77)
- Sessile oak stand Eberswalde, data for 1976 (112 years old) , 2001 (136)

The stands were initialised with measurements of DBH and H for single trees, the bole height was estimated.

Program "Holzernte 6.0"

The program was developed by the FVA Baden-Württemberg (Germany) and adapted by LFE (Brandenburg, Germany). The program allows to calculate timber grades, harvest costs and revenues.

Stem taper function

$$r(H_{rel}) = \alpha \cdot (1 - H_{rel}^3) + \beta \cdot (\ln(H_{rel}))$$

$$\alpha = a_0 + a_1\left(\frac{1}{\ln(H^{\frac{1}{DBH}})}\right) + a_2\left(\frac{1}{(\frac{H}{DBH})^2}\right)$$

$$\beta = b_0 + b_1\left(\frac{1}{\ln(H^{\frac{1}{DBH}})}\right) + b_2\left(\frac{1}{(\frac{H}{DBH})^2}\right)$$

r – radius [cm]
H_{rel} – relative height
a_i, b_i – dimensionless species-specific parameters

We applied the flexible stem taper function from Pain and Boyer (1996), adapted by Schmidt (2001) for pine and oak.

Results: Comparison of single tree data

Analysis of pine stems from Chorin 1971, 1990

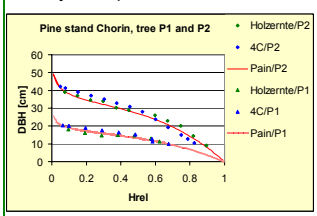


Fig. 1 Taper curve of two pine stems P1 and P2 (see Tab. 1), calculated with "Holzernte" , 4C and the Pain-function (over-bark). The diameter values of 4C and "Holzernte" are the top and mid diameters of various timber grades.

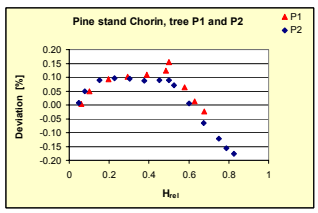


Fig. 2 Relative deviation of stem diameters (over-bark) calculated with 4C and the Pain-function for P1 and P2 (Tab. 1). 4C overestimates the stem diameter below the crown base and underestimates the diameter above crown base. The deviations are similar for the younger (P1) and the older tree (P2).

Analysis of oak stems from Eberswalde 1976, 2001

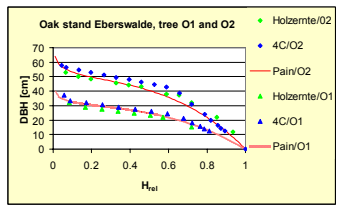


Fig. 3 Taper curve of two oak stems O1 and O2 (see Tab. 1). 4C calculates higher diameters (over-bark) below the crown base than "Holzernte". For tree O1 the over-bark diameters calculated with the Pain-function are similar to the values of 4C and "Holzernte".

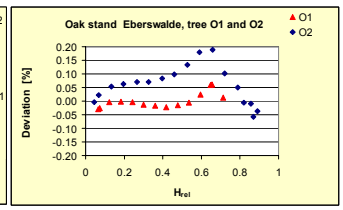


Fig. 4 The deviations of over-bark diameter calculated with 4C from the diameter calculated with the Pain-function are relatively high for the older tree (O2) with a high DBH (see Tab. 1). In this case 4C particularly overestimates the diameter around the DCRB.

Table 1: Overview of tree characteristics and comparison of calculated stem volume for two Scots pine and two Sessile oak trees

ID	Species	Year	BHD [cm]	H [m]	Volume (over-bark) [m³] Holzernte	4C	Pain
P1	pine	1971	20.5	21.5	0.34	0.34	0.32
P2	pine	1990	42.05	27.5	1,78	1.74	1.64
O1	oak	1976	34.2	24.3	1.15	1.18	1.15
O2	oak	2001	56.95	31.3	4.12	4.38	3.75

Summary 1

The model 4C slightly overestimates the stem volume of trees with higher stem dimensions (diameter and length) in comparison to values calculated with the Pain-function. The modelled stem volumes are in a good accordance with the results obtained with "Holzernte". The deviation in stem volume calculated by 4C are mainly caused by the simplifying stem form assumed in 4C. Furthermore, the estimation of bole height and DCRB of the stems affect the deviation of 4C stem dimensions from values calculated with "Holzernte" and the Pain-function This stem form is unique for all species and site conditions.

Results: Comparison of stand data

For the selected years and stands the timber grades generated by 4C and the program "Holzernte" were compared. We consider only timber grades with a top diameter greater than 7 cm, and industrial wood (IN), defined by top diameter less than 7 cm and a mid diameter less than 10 cm.

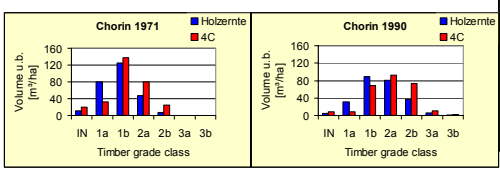


Fig. 5 For the younger Pine stand (left) as well as for the older stand (right) 4C clearly underestimates the smallest grade class and overestimates the grade class 2a and 2b. All in all, grading differs in total volume by 6-8% only (Tab. 2).

Grade	d [cm]	Pine l [m]	Oak l [m]
1a	10-14	3, 4	-
1b	15-19	3, 4	-
2a	20-24	4	3,4
2b	25-29	4	4
3a	30-34	4	4
3b	35-39	4	4
4	40-49	-	4
5	≥ 50	-	4

Definition of grade classes by length and mid diameter.

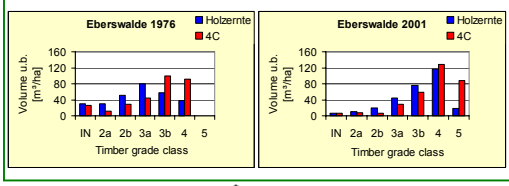


Fig. 6 The model 4C clearly overestimates the volume of timber grade number 5 with highest dimensions for the 136 years old oak stand (right). The overestimation of stem diameter below the crown base caused this deviation.

Table 2: Comparison of total volume graded by the program "Holzernte" and 4C

Stand	Volume (under-bark) [m³/ha] Holzernte	4C	Deviation [%]
Chorin 1971	271.6	293.6	8
Chorin 1990	249.1	265.2	6
Ebw. 1976	287.4	303.5	6
Ebw. 2001	293.6	325.9	11

Tab. 2 shows that 4C overestimates the total sum of all timber grades in comparison with the program "Holzernte", especially for the oldest oak stand which is characterised by trees with a high DBH.

Summary 2

The model 4C slightly overestimates the total volume of timber grades for both stands (6-11%) as well as the volume of timber grades with higher dimension (grade 2 for pine, grade 3-5 for oak). The volume of timber grades with lower dimensions are underestimated.

Corrections for timber grades and stem volume have to be taken into account in processing of timber grades generated by 4C in a wood product model and for further analyses of yield. An analytical analysis of the 4C stem model in comparison with stem taper functions is intended.

References:

Lasch, P., Badeck, F.-W., Lindner, M. and Suckow, F., 2002. Sensitivity of simulated forest growth to changes in climate and atmospheric CO_2. Forstwiss. Centralblatt, 121, Supplement 1, 155-171.

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