# Remarks on the Parameterisation of 4C

## Contents



## 1 Introduction

The model 4C is still in development. Therefore, the number of equations in use and of parameters associated with these equations can change in the future. Below, the species-specific parameters are listed which are currently in use as well as the type of data sources which can be used for determination of the parameter values. The table provides an overview of the abbreviations of variable names which will be used in the model description (currently in preparation), the variable names used in the program code, the units and a short description of the variable. One column exemplarily contains parameter values for *Pinus sylvestris* In this version you can get to these explanations by searching the text for "*abbreviation of variable* (DEF)".

It is extremely useful to collect information about photosynthesis and sensitivity of different plant life traits to weather patterns in access to the information necessary for determination of parameter values currently in use. The example parameter values for *Pinus sylvestris* which are shown on a grey shaded background are the ones which are absolutely needed for parameterisation of a new species. If no data are available for determination of parameter values, these parameters have to be adopted from parameter sets for other closely related species. In this case please report any information about similarities with other tree.

## Specific problems

Certainly, a whole suite of difficulties can arise during the search of useful information for parameterisation. It is impossible to discuss all potential problems which might be encountered in the current text, since they are extremely process specific. The model uses parameters, which can be derived from scientific results of diverse scientific disciplines. Therefore, a forester may find it easier to develop the tricks which serve to squeeze the essential information out of forestry literature while experience in ecophysiology will serve for parameter search in other types of context. Hence, it is probably inevitable, to contact the model developers directly.

A simple example may serve to illustrate, how useful information can be hidden. Imagine, the parameter for minimal specific leaf area (SLA) is to be determined. The first hurdle will consist in identifying the papers from which utilisable information can be drawn. Not in all case may the title and the list of keywords of a paper contain hints to supply this kind of information. Therefore, it is recommended to collect a wider range of bibliographic data, in order to facilitate later additional investigations in papers which do not at the first glance seem to contain the required information. The next group of obstacles is related to the existence of several parallel systems of terminology in bio-sciences. For example, the specific leaf area (SLA) can also be addressed as area per mass or area per weight. The same information can be communicated as the inverse variable, LMA (leaf mass per area), which in turn is addressed by different names (SLW, specific leaf weight or SLM, specific leaf mass). In other papers the component of SLA might even be reported separately: mass or weight of the leaves and area of the leaves, so that a search for SLA/LMA/SLW/SLM will not lead to the desired result although the information required is in the paper. The next hurdle consists in identifying necessary supplementary information. For the model the minimal SLA, i.e. the value characteristic for fully exposed sun leaves is needed. The important supplementary information might be hidden somewhere in the chapters on materials and methods. Or a source which seems to provide the information you look for cannot be used because already the uppermost "unshaded" leaves are no sun-leaves since the experiment has been done in a relatively shady glasshouse and the light level inside the glasshouse has not been reported.

The example demonstrates that it is not in all cases possible to discuss eventual problems related to parameter search a priori. It is important to stress that a precise description of the data sources used for parameterisation is a key element to further improve the parameter quality in a subsequent dialog with the model developers.

1. Table: Species-specific parameters

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | | | | Competition and mortality | |
| $a_{max}$ | max_age | [years] | 760 | maximal tree age of individual trees in absence of major disturbances | Details: amax (DEF), for many species already tabulated |
| $p_{st}$ | stol | [-] | 1 | shade tolerance, high = 5, low = 1 | Details: stol (DEF), for many species already tabulated |
| k | pfext | [-] | 0.6 | Light extinction coefficient, average coefficient for Lambert-Beer law type description of light transmission | Details: pfext (DEF) |
| | | | | Physiological parameters | |
| $\sigma_n$ | sigman | [kg N (kg root DM)$^{-1}$ y$^{-1}$] | 0.03 | specific nitrogen uptake capacity of fine roots = total whole plant nitrogen uptake per unit mass of fine roots | Details: sigman (DEF) |
| | respcoeff | [-] | 0.52 | fraction of gross production which is respired by the whole plant (autotrophe respiration) for the model variant which uses a fixed fraction (see Landsberg) | Details: respcoeff (DEF) |
| | prg | [-] | 0.2 | fraction of carbon lost as growth respiration (= growth respiration maintenance respiration not included) | Details: prg (DEF) |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | prms | [d-1] | 0.00024 | specific respiration rate of sap wood (generally at a base temperature of 15 °C, if other base temperatures were used, report these and if available information on temperature sensitivity as Q10) = fraction of mass repired per day for maintenance purposes | Details: prms (DEF) |
| | prmr | [d-1] | 0.007 | specific respiration rate of fine roots (generally at a base temperature of 15 °C, if other base temperatures were used, report these and if available information on temperature sensitivity as Q10) = fraction of mass repired per day for maintenance purposes | Details: prmr (DEF) |
| | psf | [y-1] | 0.31 | senescence rate of leaves (= 1/life span), in case of cold deciduous trees = 1 | Details: psf (DEF) |
| | pss | [y-1] | 0.05 | senescence rate of sap wood (1/(time till stop of functioning as active water conducting xylem)) | Details: pss (DEF) |
| | psr | [y-1] | 0.5 | senescence rate of fine roots (= 1/life span) | Details: psr (DEF) |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | pncr | [gN gC-1] | 0.0079 | average plant nitrogen-carbon ratio: for caluclation needed: typical nitrogen and carbon content of individual organs and mass of these organs (where possible report age and size of the trees) | Details: pncr (DEF) |
| | alphac | [-] | 0.46 | average growth increment of branches, twigs and gross roots relative to the sap wood increment (where possible report age and size of the trees) | Details: alphac (DEF) |
| | cr_frac | [-] | 0.6 | fraction of tbc (twigs, branches, roots) that is coarse roots | |
| | prhos | kg DM $(cm^3$ fresh volume$)^{-1}$ | 0.000403 | density of sap wood, will often be approximated by wood density | Details: prhos (DEF) |
| | pnus | [kg DM $cm^2$] | 0.05 | leaf mass to sap wood area (whole tree leaf mass and sap wood cross sectional area at the base of the living crown) | Details: pnus (DEF) |
| | | | | isometric and allometric relationships | |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | pha | [cm kg$^{-1}$] | 190 | for the determination of all pha parameters data sets of leaf mass and tree height for as many individual trees in different social position are needed, a description of the procedure for parameter fits to the data will be provided separately | Details: pha (DEF) |
| | pha_coeff1 | | 0.66666 | " | |
| | pha_coeff2 | | 0.33333 | " | |
| | pha_v1 | | 859 | " | |
| | pha_v2 | | 0.67 | " | |
| | pha_v3 | | 0.52 | " | |
| | crown_a | [m cm$^{-1}$] | 0.05213 | for the determination of the parameters related to crown radius - BHD - relationship data sets of crown diameter or crown projection area and breast height diameter for as many individual trees as available are needed, the instructions for parameter fits to data will be given seperately | Details: crown_a_b (DEF) |
| | crown_b | [m] | 0.48139 | " | |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | psla_min | [m2 kg-1 DM] | 4 | typical specific leaf area (SLA) = projected leaf area / leaf dry mass<br>for this and the following parameter measurements of SLA of the uppermost fully exposed sun leaves and of leaves at known relative quantum flux density are needed | Details: psla (DEF) |
| | psla_a | | 1 | change in SLA for a 100% drop in relative quantum flux density = slope of SLA - quantum flux relationship | Details: psla (DEF) |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | | | | Photosynthesis parametersall photosynthesis parameters are currently non species specific, i.e. it is not essential for model application to provide information on photosynthesis. Yet, a collection of any kind of informationen on photosynthetic capacities is useful, as: maximal carboxylation capacity (Vm), electron transport capacity (Jmax), maximal light saturated photosynthetic rate (Amax) and the correation of these capacities with leaf nitrogen contents including a description of growth and experimental conditions | |
| | phic | | 0.9 | efficiency parameter, different for evergreen and deciduous trees | Details: phic (DEF) |
| | pnc | [mg $g^{-1}$] | 20 | leaf nitrogen content | Details: pnc (DEF) |
| | kco2_25 | [Pa] | 30 | Michaelis constant for $CO_2$ at 25 °C | |
| | ko2_25 | [kPa] | 60 | Michaelis constant for $O_2$ at 25 °C | |
| | pc_25 | [-] | 3400 | $CO_2/O_2$ specificity value at 25 °C | |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | Q10_kco2 | [-] | 2.1 | Q10 of Michaelis constant for CO2 | |
| | Q10_ko2 | [-] | 1.2 | Q10 of Michaelis constant for O2 | |
| | Q10_pc | [-] | 0.57 | Q10 of specificity ratio | |
| | pb | [-] | 0.01 | mitochondrial respiration rate (Rd) / maximal carboxylation rate (Vm) | |
| | Nresp | | 0.0062 | slope of photosynthesis response to N-limitation | |
| | | | | phenology related parameters | |
| | | | | Currently three different phenology models can be parameterized, see the comments on individual parameters section below | Details pheno_models (DEF) |
| | end_bb | | 366 | average day of leaf drop, for evergreen trees = 366 if not known | end_bb (DEF) |
| | | | | Interception | |
| | ceppot_spec | [mm $m^{-2}$] | 0.4 | interception capacity of leaves in mm water per square meter leaf area | Details: ceppot (DEF) |
| | | | | parameters related to regeneration and seedling growth | |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| $M_{seed}$ [g] | seedmass | [g] | 0.006 | mass of a single seed | Details: Mseed (DEF) |
| $N_{s,max}$ [$m^{-1}$] | seedrate | [$m^{-2}$] | 10 | seed density, is prescribed by the model user | Details: Ns,max (DEF) |
| $p_{sa}$ | seeda | | 0.3927 | parameter in allometric relationship between seedling shoot mass and leaf mass | Details: psa (DEF) |
| $p_{sb}$ | seedb | | 0.6786 | " | Details: psb (DEF) |
| $p_{h1}$ | pheight1 | | 2.512 | parameter in allometric relationship between seedling height and shoot mass | Details: ph1 (DEF) |
| $p_{h2}$ | pheight2 | | 0.357 | parameter in allometric relationship between seedling height and shoot mass | Details: ph2 (DEF) |
| $p_{h3}$ | pheight3 | | - | parameter in allometric relationship between seedling height and shoot mass; currently only required for spruce | Details: ph3 (DEF) |
| | | | | decomposition parameters | |

| abbreviation of variable name | variable name in program code | unit | example: Pinus sylvestris | description of parameter and of data sets required for parameterisation | References to more detailed description and eventually already collected data |
|---|---|---|---|---|---|
| | k_opm_fol | [d-1] | 0.01 | for the determination of all k_opm und k_syn parameters results of litter incubation studies or mineralisation studies based on the 'litter bag' method are needed. Procedure of fit of parameters will be described elsewhere<br>mineralization constant of foliage litter | Details: decomp (DEF) |
| | k_syn_fol | [-] | 0.8 | synthesis coefficient of humus from foliage litter | " |
| | k_opm_frt | [d-1] | 0.01 | mineralization constant of fine root litter | " |
| | k_syn_frt | [-] | 0.8 | synthesis coefficient of humus from fine root litter | " |
| | k_opm_stem | [d-1] | 0.0005 | mineralization constant of stem wood litter | " |
| | k_syn_stem | [-] | 0.8 | synthesis coefficient of humus from stem wood litter | " |
| | k_opm_tbc | [d-1] | 0.0009 | mineralization constant of twigs, branches and coarse root litter | " |
| | k_syn_tbc | [-] | 0.8 | synthesis coefficient of humus from twigs, branches and coarse root litter | " |

## 2. Comments on individual parameters:

### *2.1 Competition and mortality parameters*

$A_{max}$ : maximum tree age [years], variable name in code: max_age

The maximum tree age is an empirical parameter for which nearly every author states different values. Here the procedure of Bugmann (1994) is adopted who compiled a large database of reported values from literature and defined maximum tree age as the average between mean and maximum value found for each tree species. The values calculated by Bugmann (1994) are given in the following Table.

| Species | Amax |
|---|---|
| Abies alba | 700 |
| Larix decidua | 850 |
| Picea excels | 930 |
| Pinus cembra | 1050 |
| Pinus montana | 300 |
| Pinus silvestris | 760 |
| Taxus baccata | 2110 |
| Acer campestre | 170 |
| Acer platanoides | 380 |
| Acer pseudoplatanus | 550 |
| Alnus glutinosa | 240 |
| Alnus incana | 150 |
| Alnus viridis | 100 |
| Betula pendula | 220 |
| Carpinus betulus | 220 |
| Castanea sativa | 1510 |
| Corylus avellana | 70 |
| Fagus silvatica | 430 |
| Fraxinus excelsior | 350 |

| Species | Amax |
|---|---|
| Populus nigra | 280 |
| Populus tremula | 140 |
| Quercus petraea | 860 |
| Quercus pubescens | 500 |
| Quercus robur | 1060 |
| Salix alba | 170 |
| Sorbus aria | 180 |
| Sorbus aucuparia | 110 |
| Tilia cordata | 940 |
| Tilia platyphyllos | 960 |
| Ulmus scabra | 480 |

***yrec*** : stress recovery time [years]

The stress recovery time denotes the number of years which are nessessary for a tree to 'forget' growth-stress. Stress is imposed on the tree as soon as the 'growth efficiency' = sapwood-increment / leaf area falls below a certain value. Stress-caused mortality is zero when there are `yrec` years of no stress. Due the lack of data, this value is currently set to three years for all three tree species. Any information about recovery times from stress-years should be collected and reported with details of evaluation or just as literature reference.

***pfext*** light extinction coefficient of leaves/needles [-]

The aim is to determine an average extinction coefficient for the visible, photosynthetically active radiation. Therefore, the best is to collect all empirically determined extinction coefficients and note as precisely as possible the experimental conditions: which stand has been used (stem number per hectar etc), at which geographical latititude? At which time of the day and season have the measurements been performed? How many repetitions have been made, what was the total stand area sampled, how was LAI determined? Additional details, if known: wood area index, ... When ever extinction coefficients have been determiend seperately for direct and diffuse light, report them seperately. This distinction shall be included in the model in future.

***stol*** shade tolerance class [-] 1-5

This parameter is also, like the preceeding parameters, an empirical one. Since it is not quite clear what the process-based background of shade tolerance of tree species is, older gap-models used this rather qualitative parameter to map the oberserved species-specific shade tolerence onto a single value. In the 4C model `stol` is asigned a value between 1 and 5 (1 = shade-intolerant, 5 = shade-tolerant) and is used to calculate a parameter for the stress mortality model. The table below gives the classification according to the qualitative approach of Ellenberg (1986) who grouped a vast number of plants into nine shade tolerance classes based on empirical observations (1 = shade-tolerant, 9 = shade-intolerant). To convert Ellenberg's values to 4C-values, the classes given by Ellenberg were multiplied by 5/9 and rounded to the nearest whole number to scale them onto the range from 1-5. Then the obtained values had to be mirrored at the median to reverse the order, because a value of 1 in the Ellenberg-scale means shade-tolerant and in 4C shade-intolerant. This was done using the formula -2*(`stol`-3)+`stol`. Any other additional classification is useful. Thus, please report additional classifications schemes, you know. In addition other sources of information are of interest, e.g. determination of minimal quantum flux density required for seedling establishment and growth.

Shade tolerance of tree species according to various authors, all values scaled to the range [ l.. .9] where 1 = shade-intolerant, 9 = shade-tolerant. (table from Bugmann 1994)

| Species | Ellenberg (1986), p. 915ff. | Ellenberg (1986), p. 82 | Landolt (1977) | Amann (1954) | Jahn (1991) | Bernatzky (1978) |
|---|---|---|---|---|---|---|
| Abies alba | 3 | 1 | 1 | 1 | 1 | |
| Larix decidua | 8 | 9 | 7 | 9 | 9 | 9 |
| Picea excelsa | 5 | 5 | 1 | 5 | 5 | 5 |
| Pinus cembra | 5 | 5 | 5 | 5 | | 5 |
| Pinus montana | 8 | 9 | 7 | | | |
| Pinus silvestris | 7 | 9 | 7 | 9 | 9 | 9 |
| Taxus baccata | 4 | 3 | 3 | 1 | 9 | 1 |
| Acer campestre | 5 | | 5 | 3 | 9 | |
| Acer platanoides | 4 | 3 | 3 | 3 | 5 | |
| Acer pseudoplatanus | 4 | 3 | 3 | 3 | 1 | |
| Alnus glutinosa | 5 | 5 | 5 | 7 | 5 | 3 |
| Alnus incana | 6 | 7 | 5 | 7 | 9 | |
| Alnus viridis | 7 | | 7 | | 9 | |
| Betula pendula | 7 | 9 | 7 | 9 | 9 | 9 |
| Carpinus betulus | 4 | 3 | 3 | 3 | 1 | 1 |
| Castanea sativa | 5 | 5 | 5 | 5 | 5 | |
| Corylus avellana | 6 | | 5 | | | 1 |
| Pagus silvatica | 3 | 1 | 3 | 1 | 1 | 1 |
| Fraxinus excelsior | 4 | 3 | 5 | 7 | 9 | 3 |
| Populus nigra | 5 | 5 | 5 | 7 | | |
| Populus tremula | 6 | 7 | 7 | 7 | | |
| Quercus petraea | 6 | 7 | 5 | 7 | 9 | |
| Quereus pubescens | 7 | 7 | 5 | 7 | 9 | |

| Species | Ellenberg (1986), p. 915ff. | Ellenberg (1986), p. 82 | Landolt (1977) | Amann (1954) | Jahn (1991) | Bernatzky (1978) |
|---|---|---|---|---|---|---|
| Quercus robur | 7 | 9 | 5 | 7 | 9 | |
| Salix alba | 5 | 5 | 5 | | | |
| Sorbus aria | 6 | 7 | 5 | 7 | 9 | |
| Sorbus aucuparia | 6 | 7 | 5 | 7 | 9 | |
| Tilia cordata | 5 | 5 | 3 | 3 | 5 | |
| Tilia platyphyllos | 4 | 3 | 3 | 5 | 5 | |
| Ulmus scabra | 4 | 3 | 3 | 5 | 5 | |

1 less shade tolerant when young

2 less shade tolerant when adult

3 more shade tolerant when young (Prentice & Helmisaari 1991)

## *2.2 Allocation parameters*

***sigman*** root activity rate [kgN kg root DM-1 year-1]

The root activity rate refers to the Nitrogen uptake of fine roots. It is expressed as kg N per fine root dry matter per year. This parameter is nessessary to calculate the partition coefficients of NPP between the tree compartments. The reason for this lies in the application of the functional balance principle in the allocation model. It says that for the synthesis of new tissue, for each unit of carbon a certain amount of Nitrogen has to be taken up by the roots to synthesize new tissue. Unfortunately this parameter is not only sensitive but also difficult to determine due to the lack of data. Any result about uptake capacity of roots in whatever form is useful.

***psf*** foliage senscence [1/year]

Senescence parameters are required for the calculation of yearly allocation. Growth is distributed between the various compartments and calculated as input (NPP) - output (senescence), where the amount lost is proportional to the actual biomass of the compartment, thus a rate.

Especially for needle the longevitiy changes with environmental conditions. Niienmets (1997) observed an increased leaf retention time with decreasing irradiance, providing an effective way of amortizing the costs of foliage contruction. Therefor, please specify the conditions under which a specific turnover time or longevity has been reported.

psf = 1 by definition for deciduous trees.

***pss*** sapwood senescence [1/year]

Sapwood senescence determines the turnover rate from sapwood to heartwood. It links tree height and foliage biomass and therefore plays an important role in the carbon balance of the tree model. Unfortunatly data concerning sapwod biomass turnover rates is seldom measured. It may be correct that heartwood is only detectable after 100 years in beeches in terms of chemical and visual analysis but probably not all of the remaining sapwood is used for water transport.

***psr*** fine root senscence [1/year]

There is a high degree of uncertainity about the actual turnover rate. Please try to specify as well as possible how the turnover rate has been determined.

***pncr*** average overall nitrogen-carbon ratio in the plant [kg N/kg C]

The nitrogen-carbon ratio is used in the funtional balance approach allocation module, where fine root activity is linked to foliage activity:

The data needed to calculate the parameter are nitrogen contents of different organs together with biomass fractions in the corresponding plant compartments.

***alphac*** coarse material to sapwood ratio [-]

Coarse material in 4C is modelled as a lumped compartment comprising coarse roots, branches and twigs. The annual production is assumed to be proportional to production of new sapwood, the proportionality constant being `alphac`. The parameter must be estimated from biomasses and sapwood data. Ideally a chronosequence would be used. Please report tree dimensions for which biomasses and sapwood have been measured.

***prhos*** sapwood densitiy [kg DM cm-3 fresh volume]

Sapwood densitiy is also an important parameter in the allocation module, linking sapwood biomass to cross sectional area, which in turn can then be related to foliage biomass via the parameter `pnus` (see below).

***pnus*** foliage to sapwood area ratio [kg cm-2]

This parameter is defined as sapwood-area which is necessary to supply one biomass-unit foilage with water. Generally, the relation is strongest for measurements at the crown base.

Mencuccini and Grace (1995) investigated the effect of climate on the sapwoodarea/leaf biomass ratio for Scots pine at to different sites in Scotland and England. They found that on the warmer and drier site the trees produced less leaf area per unit sapwood, both measured at breast height and below the living crown. The best linear fit was obtained when the sum of branch cross-sectional area was taken as independent variable. Here also the average between all measured values was considered. Therefore please report as many details on the measurements and site conditions which went into the relationship as possible.

***pha*** height growth - foliage growth relationship [cm kg-1] and other height growth parameters

Different model versions are used for height growth modelling in 4C. For determination of all the parameters needed, data sets on height and foliage mass of individual trees are needed which span a wide range of tree ages. Whenever known please also specify the social position of the tree.

***crown_a_b*** parameters for crown radius - BHD - relationship

for the determination of the parameters related to crown radius - BHD - relationship data sets of crown diameter or crown projection area and breast height diameter for as many individual trees as available are needed: a linear regression of crown radius on diameter at breast hight is calulated where crown_a is the slope and crown_b the intercept.

## *2.3 Photosynthesis and respiration parameters*

The parameters used in the photosynthesis model are mainly parameters concerning the enzym kinetics of carbon assimilation. The availability of these parameters concerning different species is very scarse. Most models which use the same parameters take values measured for spinach and wheat or other crops. It is not quite clear yet wether these parameters are species-specific or not. Although one parameter set is currently used for all species except the parameters discussed below, it is useful to report any specific enzyme kinetic results obtained on the tree species under consideration (obtained either by in vitro or in vivo gas exchange / fluorescence mehtods). In addition all data sets on photosynthetic capacities (Vcmax, Jmax, Amax, gsmax) and their relation to leaf nitrogen content are useful. Please report data, measurement methods, age of plants.

***psla*** (DEF) specific leaf area [m2/kg DW]

Specific leaf area (SLA) is a parameter which is also highly variable within a single tree and between species. It depends mainly on light environment and nutrient status and leaf age. For parameterization data are needed on average SLA of sun leaves and the rate of change with changes in relative irradiance. Please also report any information on nutritional status and age of the leaf at measurement.

***pnc*** (DEF) leaf needle N content [mg/g]

This parameter is currently not used in the model because the role of nitrogen is not yet simulated. However it is useful to collect information already

***phic*** (DEF) photosynthetic efficiency [-]

This parameter was introduced because of the senescing of the photosynthetic apparatus of evergreen coniferous trees through the years which decreases the overall photosynthetic potential of the whole leaf mass in contrast to the deciduous trees. It describes the average efficiency over all age classes. It was observed that the nitrogen content of the older needles was decreasing in favour of new needles. Therefore with the introduction of a nitrogen model and the coupling of the nitrogen model to the photosynthesis model this parameter might become obsolete, too.

***prg*** (DEF) growth respiration coefficient defined as carbon used [gC]/ (carbon incorp. [gC] + carbon used [gC]) = [-]

In 4C daily NPP is not only calculated as assimilation minus respiration but respiration is split into maintenance and growth respiration, reflecting the notion that extra energy has to be mobilized to synthesize new tissue. Growth respiration is expressed as an efficiency. This approach assumes that maintenance respiration has a higher priority for fixed carbon than does growth.

Please report organ specific results if available.

***respcoeff*** (DEF) fraction of gross production respired by the plant

There are different versions of respiration modelling that can be applied in 4C. One version builds on the theory of Landsberg (see e.g. Landsberg & Waring, 1997) that autotrophe respiration is generally close to a constant fraction of gross production. For determination of the parameter respcoeff data on gross production and respiration of all tree organs are needed. Alternatively, it can be estimated from longer time series of gross production, biomasss increment and litter fluxes.

***prms*** maintenance respiration coefficient sapwood [1/day]

In general respiration of woody tissue is lower than for foliage or fine roots (Ryan, 1994). Rates for twigs, small branches and coarse roots are usually greater, too, because they contain a higher fraction of living cells. Therefore in order to obtain a respiration rate for sapwood the respiration rates for branches and coarse roots are also considered if possible. Sapwood in 4C is assumed to consist of living, water conducting tissue. When looking at stem or sapwood respiration rates it is important to know at what time of the growing season the respiration was measured because during the growing period the measured respiration is biased by growth respiration.

Please report details of determination of the coefficient and the temperature at which it was determined. If available also report Q10 for the temperature response or parameters for the Arrhenius function.

***prmr*** maintenance respiration fine roots [1/day]

For fine roots the respiration parameters are obtained by the same procedure as for sapwood

## *2.4 Seedling parameters*

Ns,max (DEF) species specific maximum number of seeds [m-1]

We assume site specific maximum numbers of seeds because this number depends on site conditions like the density of the stand on the patch where regeneration takes place and density of the surroundings. Defaults values are assumed which have to change if more information is available or user dependent.

***Mseed*** (DEF) seed mass [g]

Data from literature or experiment were used as source for parameterization of seed mass. Mean values of seed mass are required, standard deviations of seedmass if available.With these data the initial values of shoot mass Mseed were calculated.

| species | | seed mass [g] (Mayer, Burschel/Huss) |
|---|---|---|
| Esche/Ash | Fraxinus ... | 0.07 |
| Bergahorn/maple | Acer ps. | 0.1 |
| Birke/birch | Betula pendula | 0.0002 |
| Linde/lime | Tilia cordata | 0.03 |
| Lärche/larch | Larix decidua | 0.006 |
| Zirbe/alpine stone pine | Pinus cembra | 0.25 |
| Douglasie/Douglas fir | Pseudotsuga Menziesii | 0.01 |
| Strobe/Weymouths_Kiefer | Pinus strobus | 0.019 |
| Tanne/fir | Abies alba | 0.044 |
| Hainbuche/hornbeam | Carpinus betulus | 0.033 |
| Ulme/elm | Ulmus | 0.008 |

***psa (DEF), psb (DEF)*** parameter of shoot -foliage- relation [-]

Data are necessary to parameterize following relationship between shoot (Ms) and foliage biomass (Mf):

$$M_f = p_{sa} M_s^{p_{sp}} \text{ [kg]}$$

Additionally, data for fir (*Abies alba*), maple (*Acer pseudoplatanus*) are available.

***ph1, ph2, ph3*** parameter of height -shoot-relation [-] data are necessary to parameterize the allometric relationship between height and shoot biomass Ms

$$H[cm] = ph1 \cdot M_s^{ph2} [mg]$$

$$H[cm] = 10^{ph1 + ph2 \cdot \log10(M_s) + ph3 \cdot \log10(M_s)^2} \quad Ms\ [mg]$$

Additionally, data for fir (*Abies alba*), maple (*Acer pseudoplatanus*) are available.

### 2.5 Decomposition parameters

***decomp*** (DEF) k_opm_xx and k_syn_xx all parameters related to litter decomposition.

For determination of these parameters results of litter bag or incubation experiments are needed. Because the model estimates a water and temperature depending reduction of decomposition, the parameters are given at optimal conditions. Therefore surrounding conditions (moisture and temperature resp. mean air temperature and precipitation) should be specified.

For the compartments for which no experiments have been performed also qualitative information about average decay times is useful.

### 2.6 Phenology parameters

***pheno_models***Currently three different phenology models can be parameterized with different parameter sets. A simulated annealing based optimization scheme is used to fit the parameters. Therefore, the fits can best be done at PIK. Needed as inputs are: long observational series of phenological dates and corresponding weather time series. The latter can eventually be avilable at PIK. In case somebody does want to do the fits homself please contactus and ask for a copy of Jörg Schabers dissertation which explains the details of the fitting.

***end_bb*** Currently no model is available for the end of the vegetation period (yellowing or shedding of leaves). end_bb prescribes a species speciefic avergae date for the end of the vegetation period. Can be determined as average of the dates reported in large observational data sets.

### 2.7 Interception

***ceppot_spec*** Interception capacity of leaves in mm water per square meter leaf area.

This parameter can be estimated from measurements of stand precipitation and recalculated by using the actual leaf area index. On the other site there are some publications relating this topic.

## 3 References

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