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Plant parameter values for models in temperate climates

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Abstract

Ecological, and especially hydrological models used to assess the effects of land cover changes require various input parameters for plants. Regional model applications rely on detailed information about the properties of the vegetation, especially if process-based approaches are chosen. As raising acceptable data is a time consuming issue, scientists often use globally approximated plant parameter ranges, rather than considering published data sets. The plant parameters summarised in this overview, i.e. albedo, interception capacity, maximum leaf area index, rooting depth, plant height and stomatal conductance, can be used as data for a wide range of published ecological and hydrological models. We concentrate on a presentation of values for temperate regions in order to list a manageable amount of data. Information on plant species is grouped into four main land cover types, crops, pasture (herbs, forbs, grasses), coniferous and deciduous trees. Overall, more than 1300 values for the described parameters have been gathered and present a solid data base for future applications. Further properties of species and sites, such as stand age, basal area, stock density, plant height, mean annual precipitation, mean annual temperature, coordinates and country are given, if available.

In many cases of model applications scientists used parameter spans, with no further information or testing of the distribution of data. Twenty-two of the total of 26 data sets subsumed in this data base contained sufficient values to perform a Kolmogorov–Smirnov-test. Twenty of these 22 data sets are normally distributed. In order to investigate spatial differences, the data for stomatal conductance, leaf area index and interception capacity were grouped into North American and European land cover species. Significant differences could only be determined for the leaf area index of deciduous trees and pasture species between the continents.

Keywords: Albedo; Interception capacity; Leaf area index; Plant height; Plant parameters; Rooting depth; Stomatal conductance; Temperate climate; Land use; Modelling

1. Introduction

A change in land cover, and hence plant communities, has several ecological consequences on hydrology, microclimate, soil chemistry and soil biology in a given region. In the long term, these changing conditions will further alter other soil properties. Direct effects, such as energy exchange between vegetation and atmosphere, are associated with the properties of the new vegetation. In most ecological and hydrological modelling approaches, plant parameters have to be pre-set (e.g. IHDM (Institute of Hydrology Distributed Model, Beven et al., 1987)) applied by Binley et al. (1991) to investigate runoff processes in catchments; SWAT (Soil and Water Assessment Tool; Arnold et al., 1998) to predict impacts of

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land management practices; upgrade of the Farquhar model to predict canopy photosynthesis developed by Chen et al., 1999; canopy transpiration and carbon assimilation submodel of Atmosphere-Land Exchange (ALEX) generated by Anderson et al., 2000; VIC (Variable Infiltration Capacity; Liang et al., 1994) applied by Matheussen et al., 2000 to reveal effects of land cover changes on streamflow; implementation of a terrestrial biogeochemical cycling model by Kercher and Chambers (2001); vegetation model Biosphere Energy-Transfer Hydrology Scheme (BETHY) developed by Knorr and Heimann (2001).

Usually modellers use a small amount of published information as they are not able to ascertain own data due to time constraints or limited infrastructure. Hallgren and Pitman (2000) tried to overcome the problem by searching the Current Contents database but could not find more than four alternative values for 11 out of the 19 investigated parameters needed in their sensitivity analysis of the global biome model BIOME3. Collection of reliable parameter values is usually difficult and always time consuming, due to the fact (i) that a lot of these investigations are relatively old and were published in the mid 20th century or earlier and (ii) that information has to be collected from a broad range of different scientific disciplines. As a consequence, the parameter ranges used for regional approaches are often not really suitable or sometimes even wrong (e.g. including mixed data for temperate as well as tropical vegetation in investigations of mid-latitude ecosystems). In other cases parameterisation is undertaken by looking at only a few published values, neglecting possible existing parameter ranges. Wide ranges of parameter spans result from high spatial and temporal variability and differences in the measurement techniques applied.

The stimulus for this paper was provided by previous investigations on land use changes in a German low mountain range (Fohrer et al., 2001) and the question how parameter uncertainties affect model results (Eckhardt et al., 2003). Effects of land use changes on the hydrological schemes have been debated for years (e.g. Stednick, 1996; Finch, 1998; Roberts, 2000). In most cases, the effects of deforestation, afforestation and conversion of forests to agricultural land (crops or meadows) are analysed (Bowling et al., 2000). Scientists intending to simulate land use changes and their ecological effects will always be faced with the question of how to parameterise different land cover options, as models require a broad set of various input parameters. Many of the plant parameters included are the same no matter what specific types of ecological or hydrological models are used.

Using IHDM, Binley et al. (1991) needed input data such as albedo, vegetation height, interception capacity, leaf area index and ground cover to assess the uncertainty of river discharge in Wales. Simulations of land cover change effects on streamflow by the use of the VIC model were performed by Matheussen et al. (2000). Different land cover classes in their approach were characterised by aerodynamic resistance (influenced by vegetation height), canopy resistance (depending on stomatal conductance and LAI), and root distribution. Fohrer et al. (2001) utilised SWAT-G (Eckhardt et al., 2002) to assess land use change effects on different hydrologic variables. The number of plant dependent parameters in this model is very high. The most important ones are albedo, vegetation height, interception capacity, leaf area index, stomatal conductance and rooting depth. Many of the parameters mentioned above are not only important in hydrological modelling. Terrestrial models simulating biogeochemical cycles (Kercher and Chambers, 2001), predicting CO_2 sequestration by vegetation (Knorr and Heimann, 2001), investigating photosynthesis (Chen et al., 1999) or estimating canopy transpiration and carbon assimilation (Anderson et al., 2000) also require information on leaf area index, stomatal conductance, albedo, interception capacity or rooting depth as input parameters.

Therefore, an extensive literature search has been carried out to define statistically reliable ranges for the following parameters: Albedo (a), stomatal conductance (g_s), maximum plant height (H_{max}), interception capacity of precipitation (I_c), leaf area index (LAI) and maximum root depth (RD_{max}).

2. Considered plant-specific parameters

Realising that no comprehensive overview on parameters for ecological and hydrological modelling existed, we conducted a literature research on common temperate vegetation types and plant species. The investigated plant species were grouped into four main land cover types: (i) crops, (ii) herbs, forbs and grasses (also referred to as pasture), (iii) coniferous and (iv) deciduous forests. If available, additional information on shrubs and woodland species as well as understory species in forests were added. In order to list a manageable amount of data only information on temperate climates was compiled. In cases where data for the investigated climate zone was scarce, parameter values from adjacent regions such as boreal (Estonia, Sweden, Canada) or Mediterranean (Italy, Spain) regions were also listed. Further details on stand characteristics like plant age, plant height, basal area, stock density, height above sea level (a.s.l.), mean annual precipitation, mean annual temperature, latitude, longitude and location (country) were given if available. Information on site treatments such as fertilisation or thinning were also included as soil properties in the case of maximum rooting depths.

For some of the investigated parameters it was possible to find overviews covering typical vegetation types (e.g. Geyger, 1977: LAI for grassland species) or even more or less complete reviews on selected parameters (Körner et al., 1979: stomatal conductance). This data was supplemented by recently published information to allow satisfying statistical analysis. The nomenclature of cited plant species was taken from the original text and was not converted to new classification names. As we found that approximately 5–10% of cited values in secondary literature were wrong due to conversion or typing errors, primary literature was used if accessible, to double-check data.

The published values for most of the parameters covered wide ranges. Where observations were sufficiently numerous ($N > 25$) normal distribution was tested using Lillefors modification of Kolmogorov–Smirnov-test.

2.1. Interception capacity of precipitation—I_c

Interception capacity of precipitation, in the case of forests sometimes referred to as canopy capacity, plays an important role in the calculation of water balances in hydrology and energy budgets of boundary layer climatology. Interception capacity I_c (mm) in this review is defined as the maximum amount of water left on the canopy at the end of a precipitation event under zero evaporation conditions and after drip has stopped. Surface of vegetation (i.e. the sum of leaf and woody area and their characteristics like surface structure and roughness) defines storage capacity and hence the portion of precipitation which might be evaporating from the plant into the atmosphere. Depending on the season, precipitation can occur in liquid or solid phase. Interception is usually determined by subtracting throughfall from total precipitation input overstory (Gash, 1980). To estimate values of interception capacity various techniques have been applied (Dunkerley, 2000), including artificial rain experiments and weighing of whole trees or single branches after precipitation (e.g. Aston, 1979; Teklehaimnot and Jarvis, 1991). It should be pointed out that interception capacity of precipitation relies on various factors including rainfall intensity, drop size (Calder et al., 1996), wind speed (Klaassen et al., 1996) or plant architecture (Domingo et al., 1998). Therefore, published data cover a wide range due to high temporal and spatial variability of I_c and differences in measuring techniques (Table 1).

Reliable data on I_c to parameterise pasture species and crops are difficult to find. Our estimates of these low-growing plants are based on only a limited number of published investigations. In contrast, information on forest trees is plentiful. Intercepted precipitation in a natural forest stand is a sum of interception of different compartments, i.e. over-, understory vegetation and litter. Consistently we recommend a surcharge for coniferous and deciduous trees to assess interception capacity values for whole forest stands (Table 1). Understory I_c is dominated by two values (8.1 and 11.2 mm), enhancing the mean to 3.5 mm. In view of the limited available published data, the two outliers and the fact that normally less than 100% of the soil surface is covered by understory vegetation, we propose a surcharge constant of 2.0 mm.

In contrast to common opinion, many forest species show a lower I_c than crops or pasture species (Table 1), even though some extreme values of up to 9 mm interception for coniferous forest species (i.e. *Picea* spp. and *Abies* spp.) are reported. Compared to all other main land cover types of temperate regions, deciduous forest in general show the lowest mean value of interception (1.0 mm, Table 7). This fact is even more striking in view of the generally lower mean LAI of crops compared to tree species (Table 7), a parameter very important for intercepting precipitation. An explanation might be that in view of high transpiration rates, trees evolved strategies

Table 1
Interception capacity of precipitation—I_c

I_c	Sci. name	Furth. inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
Crops													
3.0	*Avena sativa*											DE	Hoyningen-Huene (1983)
2.7	*Beta vulgaris*											DE	Hoyningen-Huene (1983)
1.9	*Hordeum vulgare*											DE	Hoyningen-Huene (1983)
1.2	*Secale cereale*											USA	Horton (1919)
3.4	*Solanum tuberosum*											DE	Hoyningen-Huene (1983)
2.1	*Triticum aestivum*											DE	Hoyningen-Huene (1983)
0.6	*Zea mays*											n.d.	Stoltenberg and Wilson (1950) in Burgy and Pomeroy (1958)
3.7	*Zea mays*											n.d.	Musgrave and Norton (1937) in Burgy and Pomeroy (1958)
1.4	*Zea mays*	4 plants per m^2										DE	Hoyningen-Huene (1983)
2.5	*Zea mays*	8 plants per m^2										DE	Hoyningen-Huene (1983)
3.0	*Zea mays*	12 plants per m^2										DE	Hoyningen-Huene (1983)
6.0	*Zea mays*	32 plants per m^2										DE	Hoyningen-Huene (1983)
Herbs, forbs, grasses													
2.3	*Andropogon furcatus*											USA, NE	Clark (1940) in Leuschner (1986)
0.8	*Beckmannia syzigachne*											USA, NE	Clark (1940) in Leuschner (1986)
2.8	*Lolium perenne*						17	300	800	38N	2W	N.Am.	Merriam (1961) in Leyton et al. (1967)
3.6	*Medicago* spp.											n.d.	Musgrave and Norton (1937) in Burgy and Pomeroy (1958)
0.7	*Molinia caerulea*											UK	Leyton et al. (1967)
2.4	*Stipa tenacissima*						17	300	800	38N	2W	ES	Domingo et al. (1998)
1.1	*Stipa-Bouteloua*	Prairie										N.Am.	Coutourier and Ripley (1973) in Leuschner (1986)
3.1	*Trifolium* spp.											n.d.	Musgrave and Norton (1937) in Burgy and Pomeroy (1958)
1.4	*Trisetum flavescens*											DE	Leuschner (1986)
1.2	n.d.	Northern Californian rangeland species										USA, CA	Burgy and Pomeroy (1958)
Shrubs, woodland													
0.8	*Acer* spp.	Hedges, single trees							110			USA, NY	Horton (1919)
1.5	*Adenostoma fasciculatum*											USA	Hicks (1943) in Zinke (1967)
1.8	*Anthyllis cytisoides*						17	300	630	38N	2W	ES	Domingo et al. (1998)
1.3	*Arctostaphylos mariposa*											USA	Rowe (unpubl.) in Grah and Wilson (1944)

1.5	*Baccharis pilularis*									USA	Grah and Wilson (1944)
										USA	Rowe (unpubl.) in Grah and Wilson (1944)
1.5	*Ceanothus cuneatus, Arctostaphylos mariposa*									USA	Hamilton and Rowe (1949)
1.0	*Cerocarpus ledifolius*									USA	Hicks (1943) in Zinke (1967)
2.0	*Erica* spp.									UK	Leyton et al. (1967)
0.8	*Fagus* spp.	Hedges, single trees					110			USA, NY	Horton (1919)
0.4	*Fraxinus* spp.	Hedges, single trees					110			USA, NY	Horton (1919)
1.8	*Photinia arbutifolia*									USA	Hicks (1943) in Zinke (1967)
0.9	*Pteridium aquilinum*									UK	Leyton et al. (1967)
1.3	*Pteridium aquilinum*									n.d.	Brookes (1950) in Leyton et al. (1967)
2.0	*Quercus dumosa, Cercocarpus betuloides, Ceanothus crassifolius*									USA	Hamilton and Rowe (1949)
0.3	*Retama spaerocarpa*				17	300	630	38N	2W	ES	Domingo et al. (1998)
0.8	*Quercus* spp.	Hedges, single trees					110			USA, NY	Horton (1919)
0.5	*Salix* spp.						110			USA, NY	Horton (1919)
0.8	*Tilia* spp.	Hedges, single trees					110			USA, NY	Horton (1919)
1.3	*Tsuga canadensis*						110			USA	Horton (1919)
0.8	*Tsuga canadensis*	Hedges, single trees					110			n.d.	Horton (1919)
0.8	*Ulmus* spp.	Hedges, single trees					110			USA, NY	Horton (1919)
1.0	n.d.	Hedges, single trees					110			USA, NY	Horton (1919)
Understory											
1.8	*Acer* spp.	Brushes and herbs								USA, NY	Horton (1919)
1.4	*Liriodendron tulipifera*									USA	Helvey (1964) in Zinke (1967)
2.3	*Pinus ponderosa*		23							USA	Rowe (1955)
8.1	*Pinus ponderosa*		75							USA	Rowe (1955)
11.2	*Pinus ponderosa*		150							USA	Rowe (1955)
0.5	*Pinus radiata*		8							USA	Rowe (1955)
1.0	*Pinus radiata*		10							USA	Rowe (1955)
1.8	*Pinus radiata*		18							USA	Rowe (1955)
3.6	*Pinus radiata*		28							USA	Rowe (1955)
Coniferous trees											
3.8	*Abies concolor*	Snowfall	100	33.0		1067	1716			USA, CA	Kittredge (1953)
6.6	*Abies concolor*	Snowfall	70	26.4		1067	1742			USA, CA	Kittredge (1953)
7.6	*Abies magnifica*	Snowfall	200	39.6		1067	2066			USA, CA	Kittredge (1953)
0.6	*Picea abies*		15							DE	Delfs et al. (1958) in Mitscherlich (1970)
1.5	*Picea abies*		25							UK	Leyton et al. (1967)
2.7	*Picea abies*		30							DE	Delfs et al. (1958) in Mitscherlich (1970)

Table 1 (*Continued*)

I_c	Sci. name	Furth. inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
3.0	*Picea abies*		59									n.d.	Weihe (1968) in Mitscherlich (1970)
3.1	*Picea abies*					2160						FR	Aussenac (1968)
4.0	*Picea abies*		60									DE	Delfs et al. (1958) in Mitscherlich (1970)
4.0	*Picea abies*		80									DE	Delfs et al. (1958) in Mitscherlich (1970)
4.7	*Picea abies*		90									DE	Benecke and van der Ploeg (1978)
9.1	*Picea rubens*		30									USA	Morey (pers. comm.) in Johnson (1942)
0.8	*Picea sitchensis*		25	12.9		3600			220	55N	2W	UK	Gash et al. (1980)
2.0	*Picea sitchensis*					3900						n.d.	Calder and Wright (1986)
2.0	*Picea sitchensis*					3100						n.d.	Calder and Wright (1986)
2.4	*Picea sitchensis*											n.d.	Olszyczka and Crowther (1981) in Klaassen et al. (1998)
2.5	*Picea sitchensis*											UK	Hancock and Crowther (1979)
2.8	*Picea sitchensis*											n.d.	Hutchings et al. (1988) in Klaassen et al. (1998)
3.0	*Picea sitchensis*											n.d.	Calder and Wright (1986)
1.2	*Picea sitchensis*	Thinned	29	8.9		4250			410	52N	3W	UK	Gash et al. (1980)
1.1	*Picea sitchensis*	Spacing 2 m										UK	Teklehaimnot and Jarvis (1991)
0.3	*Picea sitchensis*	Thinned, spacing 4 m										UK	Teklehaimnot and Jarvis (1991)
0.2	*Picea sitchensis*	Thinned, spacing 6 m										UK	Teklehaimnot and Jarvis (1991)
0.1	*Picea sitchensis*	Thinned, spacing 8 m										UK	Teklehaimnot and Jarvis (1991)
1.0	*Pinus canariensis*		28									n.d.	Kittredge et al. (1941) in Grah and Wilson (1944)
0.8	*Pinus contorta*											USA	Niederhof and Wilm (1943)
0.4	*Pinus elliottii*	Upland	30	14.1	14.9	672		1330		29N	82W	USA, FL	Liu (1998)
0.4	*Pinus elliottii*	Upland	30	17.6	11.3	464		1330		29N	82W	USA, FL	Liu (1998)
0.5	*Pinus elliottii*	Upland	30	20.7	16.7	496		1330		29N	82W	USA, FL	Liu (1998)
0.7	*Pinus elliottii*	Upland	30	15.4	25.9	1190		1330		29N	82W	USA, FL	Allen and Gholz (1995) in Liu (1998)
1.0	*Pinus nigra*					600						n.d.	Robins (1974) in Llorens and Gallart (2000)
1.1	*Pinus nigra*											USA, NH	Robins (1969, 1974) in Rutter et al. (1975)
0.3	*Pinus pinaster*			20.3		430						FR	Lankreijer et al. (1993)
0.4	*Pinus pinaster*					312						n.d.	Valente et al. (1997) in Llorens and Gallart (2000)
0.5	*Pinus pinaster*					800						n.d.	Loustau et al. (1992) in Llorens and Gallart (2000)

1.3	*Pinus ponderosa*		y									USA, CO	Johnson (1942)
3.0	*Pinus ponderosa*		70	23.4				1067	1100			USA, CA	Rowe and Hendrix (1951)
0.3	*Pinus ponderosa*	Snowfall	28	5.0				1067	1723			USA, CA	Kittredge (1953)
2.3	*Pinus ponderosa*	Snowfall	v	39.6				1067	1716			USA, CA	Kittredge (1953)
2.3	*Pinus ponderosa*	Snowfall	70	23.4				1067	1100			USA, CA	Rowe and Hendrix (1951)
0.4	*Pinus radiata*					450						n.d.	Kelliher et al. (1992) in Llorens and Gallart (2000)
1.0	*Pinus radiata*		y	1.5								AU	Aston (1979)
1.0	*Pinus radiata*											USA	Grah and Wilson (1944)
0.8	*Pinus resinosa*	Thinned	40	17.2		1236						USA, CT	Voigt and Zwolinski (1964) in Zinke (1967)
0.5	*Pinus strobus*	Thinned	40	12.5		1236						USA, CT	Voigt and Zwolinski (1964) in Zinke (1967)
0.3	*Pinus sylvestris*		23	2.8	5.0	2900			185	60N	16E	SE	Perttu et al. (1980)
0.6	*Pinus sylvestris*		125	15.6	15.0	400			185	60N	16E	SE	Perttu et al. (1980)
0.7	*Pinus sylvestris*		60	12.6	20.0	1200			185	60N	16E	SE	Perttu et al. (1980)
0.8	*Pinus sylvestris*					800						n.d.	Gash and Morton (1978)
1.0	*Pinus sylvestris*		41	15.0		1870			10.0	57N	3W	UK	Gash et al. (1980)
1.2	*Pinus sylvestris*					764						ES	Llorens and Gallart (2000)
1.3	*Pinus sylvestris*					2400						ES	Llorens et al. (1997) in Llorens and Gallart (2000)
1.5	*Pinus sylvestris*					1782						ES	Llorens and Gallart (2000)
1.6	*Pinus sylvestris*					3600						n.d.	Rutter (1963, 1975) in Llorens and Gallart (2000)
2.0	*Pinus sylvestris*					1400						ES	Llorens and Gallart (2000)
2.3	*Pinus sylvestris*					509						ES	Llorens and Gallart (2000)
2.7	*Pinus sylvestris*					2674	7.3	952				ES	Llorens and Gallart (2000)
3.0	*Pinus sylvestris*					1520						FR	Aussenac (1968)
2.0	*Pinus sylvestris, Picea abies*					1476						n.d.	Bringfelt and Harsmar (1974) in Llorens and Gallart (2000)
1.0	*Pinus* spp.		12									RU	Lokhov (1936) in Grah and Wilson (1944)
1.6	*Pinus sylvestris, Quercus* spp., *Fagus sylvatica*		80	16.9	39.3	848			600			DE	Mitscherlich and Moll (1970)
2.1	*Pseudotsuga menziesii*											USA, NH	Robins (1969, 1974) in Rutter et al. (1975)
2.4	*Pseudotsuga menziesii*		27	18.0		800						NL	Aston (1979)
2.4	*Pseudotsuga menziesii*	Thinned weakly	35	19.9	48.5	1257			600			DE	Mitscherlich and Moll (1970)
3.1	*Pseudotsuga menziesii*	Thinned moderately	35	19.5	40.2	1090			600			DE	Mitscherlich and Moll (1970)
1.6	*Pseudotsuga menziesii*	Thinned heavily	35	19.8	33.9	800			600			DE	Mitscherlich and Moll (1970)
0.9	*Taxodium asecendens, Pinus elliottii, Nyssa sylvatica*	Wetland		13.6	18.5	2062		1330		29N	82W	USA, FL	Liu (1998)

Table 1 (*Continued*)

I_c	Sci. name	Furth. inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
0.9	*Taxodium asecendens, Pinus elliottii, Nyssa sylvatica*	Wetland		13.5	17.2	1266		1330		29N	82W	USA, FL	Liu (1998)
1.1	*Taxodium asecendens, Pinus elliottii, Nyssa sylvatica*	Wetland		13.9	14.6	2700		1330		29N	82W	USA, FL	Liu (1998)
2.2	*Taxodium distichum*		64	27.0	73.6	722			1140	35N	80W	USA, NC	Oren et al. (2001)
2.5	n.d.	Snowfall	v	46.2				1067	1841			USA, CA	Kittredge (1953)
6.4	n.d.	Snowfall	v	36.3				1067	1832			USA, CA	Kittredge (1953)
Deciduous trees													
0.6	*Acacia longifolia*		y	1.5								AU	Aston (1979)
1.0	*Acer* spp.								110			USA, NY	Horton (1919)
0.8	*Aesculus californica*											USA	Hamilton and Rowe (1949)
1.5	*Aesculus* spp.								110			USA, NY	Horton (1919)
0.6	*Carpinus betulus*		60									UK	Leyton et al. (1967)
1.0	*Carpinus betulus*		60									UK	Leyton et al. (1967)
0.4	*Eucalyptus cinerea*		y	1.5								AU	Aston (1979)
0.3	*Eucalyptus dives*		y	1.5								AU	Aston (1979)
0.5	*Eucalyptus maculata*			1.5								AU	Aston (1979)
0.3	*Eucalyptus mannifera*		y	1.5								AU	Aston (1979)
0.2	*Eucalyptus viminalis*		y	1.5								AU	Aston (1979)
0.8	*Eucalyptus pauciflora*		y	1.5								AU	Aston (1979)
0.4	*Eucalyptus* spp.											n.d.	Crockford and Richardson (1990) in Klaassen et al. (1998)
0.6	*Eucalyptus* spp.											n.d.	Dunin et al. (1988) in Klaassen et al. (1998)
0.6	*Fagus sylvatica*											n.d.	Weihe (1968) in Mitscherlich (1970)
2.6	*Fagus sylvatica*		120									DE	Benecke and van der Ploeg (1978)
1.9	*Fagus sylvatica, Carpinus betulus*											FR	Aussenac (1968)
1.0	*Fagus* spp.								110			USA, NY	Horton (1919)
0.5	*Fraxinus* spp.								110			USA, NY	Horton (1919)
0.8	*Liquidamber styraciflua*											USA	Paul and Burgy (1961) in Zinke (1967)
1.0	*Quercus robur*		60	10.5	33.5	12277						UK	Thompson (1972)
0.6	*Quercus rubra*			17.3		600						NL	Lankreijer et al. (1993)
2.7	*Quercus rubra, Fagus sylvatica, Larix leptolepus*			22.0								NL	Klaassen et al. (1996)

0.8	*Quercus rubra, Liriodendron tulipifera, Acer rubrum, Robinia pseudoacacia, Nyssa sylvatica, Betula lenta, Magnolia acuminata*		50	1524	792	USA, VA	Trimble and Weitzman (1954)
1.3	*Quercus* spp.				110	USA, NY	Horton (1919)
1.3	*Tilia* spp.				110	USA, NY	Horton (1919)
1.0	*Ulmus* spp.				110	USA, NY	Horton (1919)
1.0	n.d.	Orchard			110	USA, NY	Horton (1919)
1.6	n.d.					USA	Helvey and Patric (1965) in Zinke (1967)
2.0	n.d.					USA	Morey (pers. comm.) in Johnson (1942)

I_c (mm)—interception capacity of precipitation. Sci. name: scientific names for species were taken as published by authors and not transformed into current nomenclature; n.d.: no details given; Furth. Inf.: further information given in literature; Age: y: young, v: various; PlaH: plant height (m); BasA: basal area ($m^2\ ha^{-1}$); StoD: stock density (ha^{-1}); MAT: mean annual temperature (°C); MAP: mean annual precipitation (mm); Hei: height above sea level (m); Lat: latitude (°); Lon: longitude (°); Country: N.Am.: North America; abbreviation of countries follows ISO 3166; Source: unpubl.: unpublished; pers. comm.: personal communication.

to reduce interception losses and "harvest" water by promoting throughfall or stemflow.

Information on the differences of I_c between leafed and unleafed deciduous trees are scarce and no clear statement on the effects of the leafless stage can be derived. On the one hand, Leyton et al. (1967) and Thompson (1972) reported a reduced I_c in winter during the unleafed period for *Carpinus betulus* (−37%) and for a *Quercus robur* coppice (−60%). On the other hand, Reynolds and Henderson (1967) reported even an increase of I_c for beech and larch trees in the leafless period, which Thompson (1972) attributed to the greater exposure of woody parts, mosses and lichens. Thinning, and hence a change in stand structure, does not generally result in an increase or decrease of interception capacity (see data for coniferous trees, Tables 1 and 7).

2.2. Leaf area index—LAI

Leaf area index is an important parameter in most of the existing ecological and hydrological models, as it determines photosynthesis, transpiration rates, as well as light and water interception. In consequence, the uncertainty of the potential maximum LAI may contribute considerably to the uncertainty of the model results (Eckhardt et al., 2003).

Various destructive and non-destructive methodologies have been used to determine LAI of plants, including e.g. hemispherical photography, sunfleck ceptometers, and other optical instruments like TRAC, LAI-2000 or LI-COR (detailed descriptions of techniques are presented by Chen et al., 1997). Calibration and correcting factors have to be determined for all non-destructive, optically-based methods to determine LAI. Direct litterfall measurements with littertraps were used by Chason et al. (1991) or Cutini et al. (1998) to determine LAI whereas Chen (1996) and Chen et al. (1997) and Fassnacht et al. (1994) completely harvested whole trees to derive appropriate values and set up fitting functions to calibrate their optical methods. It has to be taken into account that all methods have advantages as well as disadvantages in estimating LAI and data is not always directly comparable.

The annual course of LAI for deciduous trees peaks during the height of growing season, whereas LAI of coniferous stands vary far less over the year. Some deciduous trees keep old leaves till next season's budding whilst other species completely shed leaves. LAI of plants, especially grasses, consists of photosynthetically active green and senescent leaves. Even though old leaves do not influence photosynthesis, they still play an important role in intercepting precipitation. Therefore, as in the case of modelling water interception, a LAI greater than zero has to be maintained throughout the year for forests and pasture species in contrast to agricultural sites, which start with a LAI of zero after ploughing. Information on this lower bound of LAI, here referred to as minimum LAI or LAI_{min} is relatively scarce. Published LAI_{min} for grassland species are in a range between 0.3 and 2.0 (Calvet et al., 1998; Mitchell et al., 1998; Morrow and Friedl, 1998). Measurements of LAI in wintertime for *Fagus sylvatica* (Prskawetz and Lexer, 2000) or assessments of area indices of branches and stems for *Populus tremoluides* (Kucharik et al., 1998) reveal a highest LAI_{min} of 1.1. The area index of woody parts of coniferous trees can be assumed to be around 0.5, covering a range of 0.2 and 0.9 (Deblonde et al., 1994; Kucharik et al., 1998; Law et al., 2001).

In general, published LAI for coniferous trees and pasture are somewhat higher than those for deciduous trees, both exceeding LAI for crops by a factor of approximately 1.4–1.7 (Tables 2 and 7). As some models need information on LAI of whole stands, a surcharge for understory and litter has to be added to the LAI of trees to obtain the integrated total LAI of a given forest stand. We therefore listed values for understory as well as shrubs and woodland so modellers can sum up the needed LAI for their purpose. On average we assume that a surcharge for understory vegetation and litter of approximately 2.0 should be added to total LAI of deciduous and coniferous forests stands.

Treatments such as fertilisation of pasture (Aerts and de Caluwe, 1994) or thinning of trees might have a strong effect on LAI. For example, in a high mountain pasture of the Black Forest (Germany) LAI rose from approximately 1.2 to 8.8 after 3 years of consecutive fertilization (Geyger, 1977). Narrow plant spacing compared to broad plant spacing in crop stands led to rising LAI (Hoyningen-Huene, 1983), whereas thinning in deciduous forest reduced LAI (Bréda and Granier, 1996; Cutini et al., 1998).

Table 2
Leaf area index—LAI

LAI	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
Crops													
3.5	*Avena sativa*											DE	Hoyningen-Huene (1983)
5.1	*Beta vulgaris*											DE	Hoyningen-Huene (1983)
2.4	*Beta vulgaris*											DE	Schrödter (1985)
3.6	*Beta vulgaris*											DE	Schrödter (1985)
3.8	*Beta vulgaris*											DE	Hoyningen-Huene (1983)
4.2	*Beta vulgaris*											DE	Sommer and Bramm (1978) in Hoyningen-Huene (1983)
3.1	*Brassica oleracea acephale*									40S		NZ	Brougham (1960)
3.9	*Glycine max*	Late season								44N	5E	FR	Olioso et al. (1996) in Calvet et al. (1998)
4.0	*Glycine max*									43N	1W	FR	Goutorbe (1991) in Calvet et al. (1998)
1.8	*Helianthus annuus*											n.d.	Hiroi and Monsi (1966) in Saugier (1976)
3.0	*Helianthus annuus*											n.d.	Anderson (1970) in Saugier (1976)
3.6	*Helianthus annuus*											FR	Eckhardt et al. (1971) in Saugier (1976)
3.9	*Helianthus annuus*											n.d.	Laisk (1969) in Saugier (1976)
4.1	*Helianthus annuus*											n.d.	Nilson (1968) in Saugier (1976)
1.8	*Hordeum vulgare*											DE	Schrödter (1985)
2.2	*Hordeum vulgare*											DE	Klapp (1967) in Hoyningen-Huene (1983)
2.4	*Hordeum vulgare*											DE	Schrödter (1985)
7.1	*Pennisetum typhoides*								108	14S	132E	AU	Begg et al. (1964)
5.2	*Solanum tuberosum*											DE	Hoyningen-Huene (1983)
2.3	*Triticum aestivum*											DE	Schrödter (1985)
2.9	*Triticum aestivum*											DE	Schrödter (1985)
3.1	*Triticum aestivum*											DE	Schrödter (1985)
3.6	*Triticum aestivum*											DE	Schrödter (1985)
4.6	*Triticum aestivum*											DE	Hoyningen-Huene (1983)
2.8	*Zea mays*									52N	5E	NL	Jacobs and van Pul (1990)
3.5	*Zea mays*									43N	1E	FR	Cabelguenne et al. (1990) in Calvet et al. (1998)
3.9	*Zea mays*									52N	5E	NL	Jacobs and van Pul (1990)
3.6	*Zea mays*											DE	Hoyningen-Huene (1983)
7.4	*Zea mays*									40S		NZ	Brougham (1960)
2.1	*Zea mays*	Narrow spacing										DE	Schrödter (1985)
3.3	*Zea mays*	Narrow spacing										DE	Schrödter (1985)

Table 2 (*Continued*)

LAI	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
3.1	*Zea mays*	Broad spacing										DE	Schrödter (1985)
6.4	*Zea mays*	Broad spacing										DE	Schrödter (1985)
4.0	*Zea mays*	4 plants per m^2										DE	Hoyningen-Huene (1983)
3.3	*Zea mays*	8 plants per m^2										DE	Hoyningen-Huene (1983)
3.8	*Zea mays*	12 plants per m^2										DE	Hoyningen-Huene (1983)
10	*Zea mays*	32 plants per m^2										DE	Hoyningen-Huene (1983)
Herbs, forbs, grasses													
0.7	*Agropyron christatum*								1340	45N	111W	USA, MO	Olson et al. (2000)
0.4	*Agropyron christatum*	Grazed							1340	45N	111W	USA, MO	Olson et al. (2000)
5.5	*Agropyron dasystachyum, Kocleria cristata*							350				CA, SK	Robins and Ripley (1973) in Ripley and Redmann (1976)
0.7	*Agropyron spicatum, Poa secunda*	Native range site							1475	45N	111W	USA, MO	Olson et al. (2000)
0.8	*Agropyron spicatum, Poa secunda*	Native range site							1500	45N	111W	USA, MO	Olson et al. (2000)
1.3	*Agropyron spicatum, Poa secunda*	Native range site							1550	45N	111W	USA, MO	Olson et al. (2000)
7.0	*Agrostietum*	Intensively managed		0.28					1770	46N	11E	IT	Wohlfahrt et al. (2001)
5.8	*Andropogon geradii*	Fert.						680				USA, NE	Mitchell et al. (1998)
0.45	*Androsace glacialis*								2950			AT	Vareschi (1951)
7.0	*Arrhenatheretum*	Intensively managed		0.80					1850	47N	11E	AT	Wohlfahrt et al. (2001)
12.9	*Arrhenatherum, Agropyro-Rumicion*			1.20					10			DE	Geyger (1964)
13.6	*Arrhenatherum, Agropyro-Rumicion*			1.50					10			DE	Geyger (1964)
16.2	*Arrhenatherum, Agropyro-Rumicion*			1.70					10			DE	Geyger (1964)
6.9	*Arrhenatherum, Cirsio-Polygonum*			1.50					5			DE	Geyger (1964)
6.3	*Bromus erectus*								520			CH	Niklaus et al. (1998)
6.8	*Bromus erectus*	Elevated CO_2							520			CH	Niklaus et al. (1998)
2.6	*Bromus inermis*											USA, NE	Engel et al. (1987)
5.1	*Bromus inermis*	Fert.						680				USA, NE	Mitchell et al. (1998)
5.2	*Bromus inermis*	Fert. 168 kg N										USA, NE	Engel et al. (1987)
6.8	*Bromus inermis*	Fert. 336 kg N										USA, NE	Engel et al. (1987)
4.9	*Calamagrostis canescens*			1.60					10			DE	Geyger (1964)
5.3	*Calamagrostis canescens*			1.60					10			DE	Geyger (1964)
6.1	*Carex acutiformis*	Fert. 33 kg N										NL	Aerts and de Caluwe (1994)
15.3	*Carex acutiformis*	Fert. 200 kg N										NL	Aerts and de Caluwe (1994)
1.5	*Carex diandra*	Fert. 33 kg N										NL	Aerts and de Caluwe (1994)
6.7	*Carex diandra*	Fert. 200 kg N										NL	Aerts and de Caluwe (1994)

9.9	*Carex gracilis*		2.00		10			DE	Geyger (1964)
2.1	*Carex rostrata*	Fert. 33 kg N						NL	Aerts and de Caluwe (1994)
6.3	*Carex rostrata*	Fert. 200 kg N						NL	Aerts and de Caluwe (1994)
5.5	*Caricetum sempervirentis*	Abandoned meadow	0.22		1770	46N	11E	IT	Wohlfahrt et al. (2001)
5.1	*Cirsio-Polygonum*		1.20		10			DE	Geyger (1964)
6.7	*Cirsio-Polygonum*		1.75		10			DE	Geyger (1964)
7.6	*Cirsio-Polygonum*		1.60		10			DE	Geyger (1964)
8.2	*Cirsio-Polygonum*		1.20		10			DE	Geyger (1964)
8.4	*Cirsio-Polygonum*		0.80		10			DE	Geyger (1964)
10.1	*Cirsio-Polygonum*		1.80		10			DE	Geyger (1964)
11.7	*Cirsio-Polygonum*		1.60		10			DE	Geyger (1964)
15.5	*Cirsio-Polygonum*		1.40		10			DE	Geyger (1964)
6.2	*Cirsium oleraceum-Arrhenatherum elatior*				5			DE	Geyger (1977)
4.8	*Crepido cynosyretum*		0.14		1565	46N	11E	IT	Wohlfahrt et al. (2001)
6.4	*Dactylis glomerata*					40S		NZ	Brougham (1960)
0.6	*Festuca idahoensis, Agropyron spicatum*	Native range site			1770	45N	111W	USA, MO	Olson et al. (2000)
1.3	*Festuca idahoensis, Agropyron spicatum*	Native range site			1600	45N	111W	USA, MO	Olson et al. (2000)
3.0	*Festuca rubra, Alopecurus pratensis, Poa pratensis*	Fert.			200			DE	Geyger (1977)
6.0	*Festuca rubra, Alopecurus pratensis, Poa pratensis*	Fert.			200			DE	Geyger (1977)
10.5	*Festuco-Cynosuretum trifoliosum*				1000			DE	Geyger (1977)
9.0	*Festuco-Cynosuretum trifoliosum*	Fert.			1500			DE	Geyger (1977)
5.9	*Flavescentis*	Lightly managed	0.48		1850	47N	11E	AT	Wohlfahrt et al. (2001)
4.4	*Geranio trisetetum*	Lightly managed	0.30		1520	46N	11E	IT	Wohlfahrt et al. (2001)
8.7	*Glyceria maxima*		1.20		10			DE	Geyger (1964)
1.2	*Leondonton helveticus-Nardetum*				1500			DE	Geyger (1977)
6.0	*Lolium perenne*	Perennial				40S		NZ	Brougham (1960)
6.5	*Lolium*perenne × Lolium *multiflorum*	Short-rotation				40S		NZ	Brougham (1960)
2.4	*Molinia cerulea*							UK	Leyton et al. (1967)
3.7	Nardetum	Lightly managed	0.16		1770	46N	11E	IT	Wohlfahrt et al. (2001)
4.9	*Panicum virgatum*	Fert. 110 kg N		680				USA, NE	Mitchell et al. (1998)
8.7	*Petasites hybrides*		1.60		10			DE	Geyger (1964)
4.8	*Phragmitis communis*		3.20		5			DE	Geyger (1964)
8.0	*Phragmitis communis*		2.75		5			DE	Geyger (1964)
10.7	*Phragmitis communis*		3.30		10			DE	Geyger (1964)

Table 2 (*Continued*)

LAI	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
11.6	*Poa trivialis, Dactylis glomerata, Heracleum sphondylium*								1050			AT	Vareschi (1951)
11.0	*Polytrichum sexangulare, Bryum* spp.								2680			AT	Vareschi (1951)
2.9	*Schizachyrium scoparium, Bouteloua* spp.	.					14.2	1166	350	36N	96W	USA, OK	Burba and Verma (2001)
4.9	*Siversio nardetum strictae*	Abandoned		0.30					1520	46N	11E	IT	Wohlfahrt et al. (2001)
4.7	*Thinopyrum intermedium*	Fert. 110 kg N						680				USA, NE	Mitchell et al. (1998)
3.0	*Trifolium repens*									40S		NZ	Brougham (1960)
3.5	*Trifolium repens*									40S		NZ	Brougham (1960)
4.8	*Trifolium pratense*									40S		NZ	Brougham (1960)
1.5	*Trisetum flavescentis hercynicum*								460			DE	Geyger (1977)
9.0	*Trisetum flavescentis hercynicum*	Fert.							460			DE	Geyger (1977)
10.5	*Veronico-Cirsio-Polygonum*			1.60					10			DE	Geyger (1964)
14.7	*Veronico-Cirsio-Polygonum*			1.50					10			DE	Geyger (1964)
1.8	n.d.	Grassland								52N	5E	NL	Chen et al. (1997) in Calvet et al. (1998)
2.9	n.d.	Fallow								43N	1E	FR	Bessemoulin et al. (1996) in Calvet et al. (1998)
5.5	n.d.	Pasture							548			AT	Rosset et al. (1997)
5.8	n.d.	Pasture							915			AT	Rosset et al. (1997)
6.5	n.d.	Pasture							1367			AT	Rosset et al. (1997)
Shrubs, woodland													
0.5	*Artemisia tridentata*			15.0				200	1200	44N	121W	USA, OR	Gholz (1982)
4.3	*Kalmia latifolia, Rhododendron maximum*											n.d.	Whittaker (1966)
3.7	*Pinus chihuahuana, Quercus hypoleucoides*		101	7.5	26.0	2780			2040			USA, AZ	Whittaker and Niering (1975)
1.6	*Pteridium aquilinum*											UK	Leyton et al. (1967)
1.8	*Quercus* spp.		117	5.3	4.0	190			1310			USA, AZ	Whittaker and Niering (1975)
2.8	*Rhododendron catawbiense*								2010			USA, TN	Whittaker (1962)
2.8	*Rhododendron catawbiense, Kalmia latifolia*								975			USA, TN	Whittaker (1962)

3.0	*Rhododendron catawbiense, Kalmia latifolia*							975			USA, TN	Whittaker (1962)
4.5	*Rhododendron maximum, Kalmia latifolia*							1500			USA, TN	Whittaker (1962)
2.0	n.d.		115	2.7	4.3	570		2040			USA, AZ	Whittaker and Niering (1975)
2.7	n.d.										UK	Leyton et al. (1967)
4.7	n.d.										USA	Whittaker (1966)
13.1	n.d.										USA	Whittaker (1966)
Understory												
2.3	*Adenostyles alliaria, Chaerophyllum cicutarium, Struthiopteris germanica*	OS *Alnus incana*, LAI 8.8									AT	Vareschi (1951)
0.4	*Arctostaphylos patula, Purshia tridentata*	OS *Pinus ponderosa*, LAI 0.6; regeneration after clearcut	14	4.3		344	615	940	44N	122W	USA, OR	Law et al. (2001)
1.5	*Carex alba, Brachypodium pinnatum, Carex flacca*	OS *Pinus sylvestris*, LAI 1.8									DE	Wedler et al. (1996)
0.5	*Purshia tridentata, Pteridium aquilinum, Fragia vesca, Arctostyphylos patula*	OS *Pinus ponderosa*, LAI 1.7	85	13.8		440	615	940	44N	122W	USA, OR	Law et al. (2001)
3.2	*Swida sanguinea*	OS *Populus canadensis*, LAI 4.9	27	3.5				116	48N	17E	SI	Oszlányi (1995)
2.0	*Vaccinium myrtillus*	OS, *Piceetum-myrtillosum*, LAI 3.9									AT	Vareschi (1951)
0.2	n.d.	OS *Acer platanoides*, LAI 5.0									RU	Rauner (1976)
0.3	n.d.	OS *Populus tremula*, LAI 7.1									RU	Rauner (1976)
0.3	n.d.	OS *Tilia cordata*, LAI 4.8									RU	Rauner (1976)
0.5	n.d.	OS *Quercus robur*, LAI 4.6									RU	Rauner (1976)
0.5	n.d.	OS *Quercus-Fagus sylvatica*, LAI 2.6									USA, GA	Monk et al. (1970)
0.7	n.d.	OS *Betula verrucosa*, LAI 5.3									RU	Rauner (1976)
1.0	n.d.	OS *Quercus-Betula*, LAI 3.8									DE	Ellenberg (1939) in Geyger (1964)
1.0	n.d.	OS *Quercus-Carpinus*, LAI 7.0									DE	Ellenberg (1939) in Geyger (1964)

Table 2 (*Continued*)

LAI	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
1.0	n.d.	OS *Quercus-Carpinus*, LAI 9.0										DE	Ellenberg (1939) in Geyger (1964)
2.0	n.d.	OS *Quercus-Betula*, LAI 6.0										DE	Ellenberg (1939) in Geyger (1964)
13.3	n.d.	OS *Picea-Vaccinium myrtillus*, LAI 3.9										AT	Vareschi (1951)
Coniferous trees													
15.5	*Abies concolor*		124	25.5	58.6	1510			2340			USA, AZ	Whittaker and Niering (1975)
12.3	*Abies fraseri*			17.0	40.0	710			1920	35N		USA, TN	Whittaker (1966)
14.8	*Abies fraseri, Picea rubens*		161	25.0	55.6	840			1800	35N		USA, TN	Whittaker (1966)
14.7	*Abies lasiocarpa*		106	33.5	57.8	590			2720			USA, AZ	Whittaker and Niering (1975)
1.0	*Juniperus occidentalis*				27.8	669		250	1356	44N	121W	USA, OR	Gholz (1982)
5.0	*Larix decidua*											USA, WI	Bolstad and Gower (1990) in Fassnacht et al. (1994)
5.1	*Larix decidua*		28		38.3	1040						USA, WI	Gower and Norman (1991)
3.6	*Larix leptolepis*			10.4		1100				42N	76W	USA	Allen (1968) in Jarvis et al. (1976)
5.6	*Picea abies*		30	12.6	45.9	2343	6.0	1500	1050	48N	7E	FR	Lu et al. (1995)
6.5	*Picea abies*		y			d			1000	48N	7E	FR	Granier et al. (1996)
8.4	*Picea abies*		72	27.5		800				48N	12E	DE	Baumgartner and Alfreit (unpubl.) in Jarvis et al. (1976)
10.4	*Picea abies*		28		37.1	1725						USA, WI	Gower and Norman (1991)
12.8	*Picea abies*		28	17.4	31.2							SE	Nilson et al. (1999)
9.3	*Picea abies, Pinus sylvestris*		70	17.8	30.7							SE	Nilson et al. (1999)
5.0	*Picea mariana*		83	10.5		4825				56N	98W	CA	Chen et al. (1997)
6.3	*Picea mariana*		78	5.0		4750				54N	105W	CA	Chen et al. (1997)
9.8	*Picea sitchensis*		25	11.5		4100				57N	2W	UK	Landsberg and Jarvis (1973) in Jarvis et al. (1976)
4.1	*Picea* spp.		132	34.0	24.0	112			850			CH	Burger (1939) in Geyger (1964)
4.3	*Picea* spp.											n.d.	Möller (1945) in Geyger (1964)
7.7	*Picea* spp.											n.d.	Möller (1945) in Geyger (1964)
8.3	*Picea* spp.		98	34.0	76.0	712			940			CH	Burger (1939) in Geyger (1964)
8.5	*Picea* spp.											CH	Burger (1941) in Geyger (1964)
9.6	*Picea* spp.		35	12.6	35.3	3148	6.5	1300	800			CH	Burger (1939) in Geyger (1964)
10.5	*Picea* spp.											CH	Burger (1939) in Geyger (1964)
12.0	*Picea* spp.											CH	Burger (1941) in Geyger (1964)
14.0	*Picea* spp.											CH	Burger (1941) in Geyger (1964)
11.0	*Picea-Abies*		42	17.6	42.9	1756	7.2	1350	690			CH	Burger (1939) in Geyger (1964)
3.9	*Piceetum-myrtillosum*		65			920			1050			n.d.	Vareschi (1951)

1.5	*Pinus banksiana*	Natural regeneration	30		20.5	2705				46N	77W	CA, ON	Deblonde et al. (1994)
1.6	*Pinus banksiana*	Plantation	30		17.3	1299				46N	77W	CA, ON	Deblonde et al. (1994)
1.7	*Pinus banksiana*	Plantation	30		20.7	1510				46N	77W	CA, ON	Deblonde et al. (1994)
2.0	*Pinus banksiana*		60		17.5	781				46N	77W	CA, ON	Deblonde et al. (1994)
2.2	*Pinus banksiana*	Plantation	30		28.0	1368				46N	77W	CA, ON	Deblonde et al. (1994)
2.5	*Pinus banksiana*		68	13.5		2800				54N	105W	CA	Chen et al. (1997)
2.8	*Pinus banksiana*		14	4.5		4750				54N	105W	CA	Chen et al. (1997)
2.0	*Pinus banksiiana*		25	1.3		23850				56N	99W	CA	Chen et al. (1997)
2.2	*Pinus banksiiana*		58	11.3		2400				56N	99W	CA	Chen et al. (1997)
2.8	*Pinus contorta*		71	10.0		1700				39N	140E	JP	Bergen (1971) in Jarvis et al. (1976)
14.4	*Pinus contorta, Abies lasiocarpa*			12.5		3200			2750	41N	106W	USA, WY	Pataki et al. (2000)
0.8	*Pinus densiflora*		37	4.5		2300				36N	79W	USA	Kondo (1971) in Jarvis et al. (1976)
1.7	*Pinus densiflora*		37	23.0		750				41N	106W	USA	Kondo (1971) in Jarvis et al. (1976)
4.6	*Pinus halapensis*			10.6	16.8	812	13.6	353	700	39N	1W	ES	López-Serrano et al. (2000)
2.3	*Pinus pinaster*			20.3		430						FR	Lankreijer et al. (1993)
0.6	*Pinus ponderosa*	Natural regeneration after clearcut	14	4.3		344		615	940	44N	122W	USA, OR	Law et al. (2001)
1.7	*Pinus ponderosa*		85	13.8		440		615	940	44N	122W	USA, OR	Law et al. (2001)
2.0	*Pinus ponderosa*				28.5	1152			1250	47N	113W	USA, MT	Fassnacht et al. (1994)
3.5	*Pinus ponderosa*				26.1	705		400	870	44N	122W	USA, OR	Gholz (1982)
5.9	*Pinus ponderosa*		142	18.4	46.3	1100			2470			USA, AZ	Whittaker and Niering (1975)
7.6	*Pinus ponderosa, Pinus strobiformes*		93	12.8	39.4	2700			2740			USA, AZ	Whittaker and Niering (1975)
4.7	*Pinus ponderosa, Quercus hypoleucoides*		150	15.2	34.9	1280			2180			USA, AZ	Whittaker and Niering (1975)
8.3	*Pinus radiata*											n.d.	Whitehead (unpubl.) in Jarvis and Leverenz (1983)
2.6	*Pinus resinosa*		40	15.0		2500				41N	72W	USA	Waggoner and Turner (1971) in Jarvis et al. (1976)
2.9	*Pinus resinosa*	Plantation	60		29.3	430				46N	77W	CA, ON	Deblonde et al. (1994)
4.9	*Pinus resinosa*	Plantation	60		43.3	850				46N	77W	CA, ON	Deblonde et al. (1994)
5.4	*Pinus resinosa*											USA, WI	Bolstad and Gower (1990) in Fassnacht et al. (1994)
5.8	*Pinus resinosa*				42.4	2106			500	46N	89W	USA, WI	Fassnacht et al. (1994)
6.2	*Pinus resinosa*	Plantation	60		57.3	1269				46N	77W	CA, ON	Deblonde et al. (1994)
6.4	*Pinus resinosa*		28		45.5	1970						USA, WI	Gower and Norman (1991)
3.1	*Pinus resinosa, Pinus strobus*			22.0		600				46N	77W	CA	Mukammal (1971) in Jarvis et al. (1976)
5.7	*Pinus strobus*											CH	Burger (1929) in Geyger (1964)
7.1	*Pinus strobus*		28		41.8	1180						USA, WI	Gower and Norman (1991)

Table 2 (*Continued*)

LAI	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
7.4	*Pinus strobus*											USA, WI	Bolstad and Gower (1990) in Fassnacht et al. (1994)
8.0	*Pinus strobus*											CH	Burger (1929) in Geyger (1964)
1.1	*Pinus sylvestris*		60	4.4	6.4							EE	Nilson et al. (1999)
1.5	*Pinus sylvestris*		120	24.8	14.1							SE	Nilson et al. (1999)
2.8	*Pinus sylvestris*											n.d.	Whitehead and Jarvis (unpubl.) in Jarvis and Leverenz (1983)
2.8	*Pinus sylvestris*		31	12.0		4000			201	48N	7E	n.d.	Joss and Graber (1996)
2.9	*Pinus sylvestris*								201	48N	7E	DE	Granier et al. (1996)
3.2	*Pinus sylvestris*		45	17.7	27.0							EE	Nilson et al. (1999)
3.4	*Pinus sylvestris*		70	23.6	23.5							SE	Nilson et al. (1999)
3.6	*Pinus sylvestris*		35	7.9	16.1							EE	Nilson et al. (1999)
3.7	*Pinus sylvestris*		35	8.4	18.5							EE	Nilson et al. (1999)
3.8	*Pinus sylvestris*		25	10.5	19.1							SE	Nilson et al. (1999)
4.3	*Pinus sylvestris*		41	15.5		800				52N	0E	UK	Oliver (1971) in Jarvis et al. (1976)
4.4	*Pinus sylvestris*		50	15.3	23.7							EE	Nilson et al. (1999)
4.4	*Pinus sylvestris*		55	12.8	27.0							EE	Nilson et al. (1999)
4.6	*Pinus sylvestris*		56	7.6	14.9							SE	Nilson et al. (1999)
4.9	*Pinus sylvestris*		40	14.3	32.0							SE	Nilson et al. (1999)
6.3	*Pinus sylvestris*		30	10.2	27.4							SE	Nilson et al. (1999)
7.2	*Pinus sylvestris*		31	17.2	32.7							EE	Nilson et al. (1999)
2.6	*Pinus taeda*		14	12.5		1700				36N	140E	JP	Sinclair et al. (unpubl.) in Jarvis et al. (1976)
2.7	*Pinus taeda*		12	7.1	24.8	5240	15.5	1140	130	36N	80W	USA, NC	Phillips et al. (1996)
7.8	*Pinus virginiana, Pinus strobus*			20.0	34.4	3460			610	35N		USA, TN	Whittaker (1966)
3.3	*Pinus* spp.											CH	Burger (1941) in Geyger (1964)
3.3	*Pinus* spp.		105									SE	Tiren (1927) in Geyger (1964)
3.6	*Pinus* spp.		35									SE	Tiren (1927) in Geyger (1964)
3.7	*Pinus* spp.											CH	Burger (1941) in Geyger (1964)
5.1	*Pinus* spp.		55									SE	Tiren (1927) in Geyger (1964)
5.1	*Pseudotsuga menziesii*		74	27.8	21.7	132						NL	Bartelink (1998)
7.5	*Pseudotsuga menziesii*				54.5	500		1570	410	44N	122W	USA, OR	Gholz (1982)
7.6	*Pseudotsuga menziesii*		25	18.3	36.6	1010						NL	Bartelink (1998)
7.8	*Pseudotsuga menziesii*		26			1080						CA, BC	Chen and Black (1991)
9.2	*Pseudotsuga menziesii*											n.d.	Burger (1935) in Geyger (1964)
11.0	*Pseudotsuga menziesii*											n.d.	Ungs (1981) in Jarvis and Leverenz (1983)
13.5	*Pseudotsuga menziesii*											n.d.	Burger (1935) in Geyger (1964)
15.5	*Pseudotsuga menziesii*		252	27.6	70.5	340			2650			USA, AZ	Whittaker and Niering (1975)

16.7	*Pseudotsuga menziesii, Abies concolor*		321	27.9	118.1	400			2640			USA, AZ	Whittaker and Niering (1975)
9.0	*Pseudotsuga menziesii, Abies grandis*				84.2	422		1200	365	45N	123W	USA, OR	Gholz (1982)
11.0	*Pseudotsuga menziesii, Tsuga heterophylla, Abies amabilis*				72.4	2255		2000	1500	44N	122W	USA, OR	Gholz (1982)
5.9	*Pseudotsuga menziesii, Tsuga heterophylla, Thuja placata*		50		23.8	1586						USA, OR	Turner et al. (2000)
9.5	*Pseudotsuga menziesii, Tsuga heterophylla, Thuja placata*		140		59.7	307						USA, OR	Turner et al. (2000)
9.8	*Pseudotsuga menziesii, Tsuga heterophylla, Thuja placata*		200		84.1	547						USA, OR	Turner et al. (2000)
2.2	*Taxodium distichum*		64	27.0	73.6	722	15.5	1140	130	35N	79W	USA, NC	Oren et al. (2001)
15.5	*Tsuga heterophylla*				118.2	2794		2460	200	45N	124W	USA, OR	Gholz (1982)
23.5	*Tsuga heterophylla*				111.2	1999		2460	200	45N	124W	USA, OR	Gholz (1982)
5.0	*Tsuga mertensiana*				57.2	2504		2300	1590	44N	122W	USA, OR	Gholz (1982)
Deciduous trees													
5.0	*Acer platanoides*		18	7.0								RU	Rauner (1976)
4.9	*Acer rubrum, Quercus alba*			21.5				1360	365	36N	84W	USA, TN	Chason et al. (1991)
6.2	*Aesculus octandra, Tilia heterophylla*		222	36.0	54.2	1450			1310	35N		USA, TN	Whittaker (1966)
8.8	*Alnus incana*			5.0					1050			AT	Vareschi (1951)
5.3	*Betula verrucosa*		18	7.6								RU	Rauner (1976)
4.1	*Castanea sativa*	Thinned	37	23.7	32.9	590			900	44N	12E	IT	Cutini et al. (1998)
7.0	*Castanopsis cuspidata*											JP	Kira et al. (1969) in Jarvis and Leverenz (1983)
2.8	*Eucalyptus maculata*											n.d.	Dunin and Reyenga (unpubl.) in Jarvis and Leverenz (1983)
2.0	*Eucalyptus marginata*			27.5								AU, WA	Silberstein et al. (1999)
7.0	*Fagus crenata*											JP	Kira et al. (1969) in Jarvis and Leverenz (1983)
2.9	*Fagus grandifolia*			16.0	22.2	2170			1580	35N		USA, TN	Whittaker (1966)
4.3	*Fagus sylvatica*		m	30.2	28.5	659						FR	Le Dantec et al. (2000)
4.9	*Fagus sylvatica*		90	23.5	32.1	1243			1560	42N	13E	IT	Cutini et al. (1998)
5.0	*Fagus sylvatica*											DE	Schäfer et al. (unpubl.) in Oren et al. (1999)
5.7	*Fagus sylvatica*		30	16.0	19.6	3800			300	48N	7E	FR	Granier et al. (2000)
5.7	*Fagus sylvatica*		120	22.5		429			1000	48N	7E	FR	Granier et al. (2000)
5.8	*Fagus sylvatica*		135									DE	Stickan et al. (1983)

Table 2 (*Continued*)

LAI	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
6.2	*Fagus sylvatica*											DE	Schäfer et al. (unpubl.) in Oren et al. (1999)
6.8	*Fagus sylvatica*		47	18.0	40.9	3920			1000	44N	12E	IT	Cutini et al. (1998)
7.0	*Fagus sylvatica*											DE	Ebermayer (1882) in Geyger (1964)
7.4	*Fagus sylvatica*		62	23.0	23.4	357						NL	Bartelink (1998)
8.0	*Fagus sylvatica*											CH	Burger (1940) in Geyger (1964)
8.2	*Fagus sylvatica*		y	8.0	28.7	15810				48N	16E	AT	Prskawetz and Lexer (2000)
10.0	*Fagus sylvatica*											DE	Ebermayer (1882) in Geyger (1964)
5.6	*Fagus sylvatica*	Fert.	135									DE	Stickan et al. (1983)
5.9	*Fagus sylvatica*	Thinned	47	18.0	19.6	708			1000	44N	12E	IT	Cutini et al. (1998)
6.3	*Fagus sylvatica*	Limed	135									DE	Stickan et al. (1983)
5.0	*Fraxinus* spp.											n.d.	Möller (1945) in Geyger (1964)
6.0	*Liriodendron tulipifera*											USA, TN	Hutchinson and Matt (1976) in Jarvis and Leverenz (1983)
7.4	*Liriodendron tulipifera*		29	27.0	34.2	1820			700	35N		USA, TN	Whittaker and Marks (1975)
4.9	*Populus canadensis*	Plantation	27	33.2	41.3	324			116	48N	17E	SK	Oszlányi, 1995
7.1	*Populus tremula*		25	10.5				1200				RU	Rauner (1976)
3.3	*Populus tremuloides*		60	21.0		900				54N	106W	CA, SK	Chen et al. (1997)
3.3	*Populus tremuloides*		70	21.5		828				54N	106W	CA, SK	Kucharik et al. (1998)
3.6	*Populus tremuloides*									56N	98W	CA	Chen et al. (1997)
3.8	*Populus tremuloides*			12.5		17100			2750	41N	106W	USA, WY	Pataki et al. (2000)
6.4	*Populus tremuloides*	Succession	34	16.1	31.6	2350			2550			USA, AZ	Whittaker and Niering (1975)
7.3	*Populus tremuloides, Pinus contorta, Abies lasiocarpa*			12.5		1900			2750	41N	106W	USA, WY	Pataki et al. (2000)
5.5	*Quercus alba, Liquidambar styraciflua*		80	45.0	22.1	1330	15.5	1140	130	36N	80W	USA, NC	Phillips et al. (1996)
5.3	*Quercus cerris*		40	23.2	42.3	3589			305	43N	10E	IT	Cutini et al. (1998)
6.9	*Quercus cerris*		39	22.2	34.1	4052			700	43N	12E	IT	Cutini et al. (1998)
3.8	*Quercus cerris*	Thinned	38	23.4	22.2	460			900	44N	12E	IT	Cutini et al. (1998)
4.3	*Quercus cerris*	Thinned	39	20.5	21.2	1004			700	43N	12E	IT	Cutini et al. (1998)
4.3	*Quercus cerris*	Thinned	40	22.4	28.1	2741			305	43N	10E	IT	Cutini et al. (1998)
6.0	*Quercus petrea*		35		24.6	3352			237	48N	6E	FR	Bréda and Granier (1996)
3.3	*Quercus petrea*	Thinned	35		17.6	3077			237	48N	6E	FR	Bréda and Granier (1996)
6.3	*Quercus prinus, Acer rubrum*			30.0	35.0	2130			820	35N		USA, TN	Whittaker (1966)
4.6	*Quercus robur*		18	6.5								RU	Rauner (1976)
5.5	*Quercus robur, Quercus petrea*		m	31.3	35.3	659			120	48N	2E	FR	Le Dantec et al. (2000)

3.1	*Quercus rubra*		28		11.6	1840						USA, WI	Gower and Norman (1991)
4.9	*Quercus rubra*			17.4		600						NL	Lankreijer et al. (1993)
5.0	*Quercus rubra*											USA, WI	Bolstad and Gower (1990) in Fassnacht et al. (1994)
3.4	*Quercus rubra, Acer rubrum*			20.0					315	43N	72W	USA, WI	Sakai et al. (1997)
5.4	*Quercus rubra, Fagus sylvatica, Larix leptolepus*			22.0								NL	Klaassen et al. (1996)
5.7	*Quercus rubra, Quercus alba, Quercus velutina*	Arboretum										USA, WI	Bolstad and Gower (1990) in Fassnacht et al. (1994)
6.2	*Querco-Betuletum*											DE	Ellenberg (1939) in Ellenberg (1996)
10.0	*Querco-Carpinetum*											DE	Ellenberg (1939) in Ellenberg (1996)
2.6	*Quercus-Carya pallida*											USA, GA	Monk et al. (1970)
6.5	*Quercus* spp.-*Fagus sylvatica*		*m*	30.8	30.3	746						FR	Le Dantec et al. (2000)
3.8	*Quercus-Pinus*		43	9.0	15.6	1850						USA, NY	Whittaker and Woodwell (1969) in Whittaker and Marks (1975)
2.5	*Quercus* spp.											n.d.	Möller (1945) in Geyger (1964)
3.1	*Quercus* spp.											n.d.	Möller (1945) in Geyger (1964)
6.5	*Quercus* spp.											n.d.	Ebermayer (1882) in Geyger (1964)
7.6	*Quercus* spp.	Single tree		11.6								NL	Bartelink (1998)
3.8	*Salix viminalis*	Coppice	1	3.2		20000			70	58N	26E	EE	Ross et al. (2000)
4.1	*Salix viminalis*	Coppice	3	5.1		20000			70	58N	26E	EE	Ross and Ross (1998)
4.8	*Tilia cordata*		18	11.5								RU	Rauner (1976)
6.1	n.d.	Mixed	124	20.0	26.3	1290						USA, NH	Whittaker et al. (1974) in Whittaker and Marks (1975)

LAI—leaf area index. Sci. name: scientific names for species were taken as published by authors and not transformed into current nomenclature, n.d.: no details given; Furth. Inf.: further information given in literature, OS: overstory, Fert.: fertilized; Age: m: mature, y: young; PlaH: plant height (m); BasA: basal area ($m^2\,ha^{-1}$); StoD: stock density (ha^{-1}), d: dense; MAT: mean annual temperature (°C); MAP: mean annual precipitation (mm); Hei: height above sea level (m); Lat: latitude (°); Lon: longitude (°); Country: N.Am.: North America; abbreviation of countries follows ISO 3166; Source: unpubl.: unpublished.

2.3. Albedo—*a*

The fraction of reflected to incident radiation by the sun is commonly referred to as albedo (or sometimes as reflectance). Accurate parameterisation of surface albedo is important in modelling energy balances of a given land cover (Iqbal, 1983). Estimates of available energy are needed in a variety of ecological as well as hydrological models, i.e. to calculate evapotranspiration, photosynthesis, biomass production or soil temperature. A new perspective of forestation and its impacts on carbon sequestration is highlighted by Betts (2000). Model simulations revealed that the negative radiative forcing due to CO_2 uptake by temperate and boreal forests might be offset by the positive radiative forcing induced by a decreased albedo.

Despite the direction of the incident radiation, set up by the solar elevation, reflected energy depends mostly on surface properties. Albedo values are most often given for the shortwave spectrum between 0.3 and 3.0 μm (Iqbal, 1983), including the photosynthetically active radiation for plant growth (PAR: 0.4–0.7 μm). To determine albedo values for certain plants a set of pyranometers (solarimeters) is used over the specific stand, measuring incoming and outgoing radiation simultaneously (Monteith and Szeicz, 1961). Broader scale determination of albedo is performed by using data from regional aircraft flights or satellite images, though all these techniques have to be calibrated by ground truth measurements too (Yin, 1998).

Published ranges of albedo in textbooks are often inaccurate and general values for "crops" or "forests" with no further details are given. Comprehensive overviews on data for substantial sets of various vegetation types, land covers and materials like soil, rocks and building materials were published among others by Kondratyev (1969, 1972) and Iqbal (1983). The values presented by Gates (1980) were obtained by measuring the spectral reflectance of single leaves. We focused on a selection of available data for temperate land covers and amended those where possible with recent findings (Table 3).

Mean minimum and maximum albedo values for crops, pasture and deciduous forest were similar within a range of 0.20–0.27 as opposed to coniferous forests with a substantially lower minimum of 0.11 and a mean maximum of 0.14 (Table 7). This distinction is mainly the result of general differences in canopy architecture, leaf/needle morphology and spectral reflectance properties of leaves/needles.

Furthermore, a differentiation should further be made for seasonal albedo values. Schmid et al. (2000) provided data for a mixed broad-leafed forest stand in Indiana, USA. Lowest albedo was found in February (∼0.11) whilst the highest was recorded during the initial period of foliage development (∼0.17). Towards the end of the vegetation period, albedo decreased gradually, which was attributed (i) to an increase of foliage size and hence a multiple reflection of radiation within the canopy and/or (ii) to darker leaf colour as a matter of senescence (Schmid et al., 2000). Overall albedo of deciduous and coniferous forests is further determined by snow cover in winter, where values obtained by aircraft measurements varied between 0.35 and 0.66 (Kondratyev, 1972).

Extremely low values for pasture species were reported twice (alfalfa 0.02 as well as *Schizachyrium scoparium* and *Bouteloua* spp. 0.05), extending the range for pasture species from 0.02 to 0.42. Albedo of this land cover type is strongly dependent on the portion of bare soil and its spectral reflectance properties, which itself is driven by factors like soil moisture, texture, mineral composition or humus content.

2.4. Stomatal conductance—g_s

Stomatal conductance g_s plays an important role in the plant-atmosphere water exchange and hence it is a key parameter in many ecological models (Chen et al., 1999). Diffusion of CO_2 into the mesophyll of leaves and water vapour from the leaf to the atmosphere is mainly controlled by the stomatal aperture, which is further controlled by a complex system of plant physiological processes. One has to keep in mind, that potentially maximum stomatal conductance will in fact never be measured, as environmental conditions such as CO_2 partial pressure or soil moisture always influence stomatal conductance to some extend. In the context of this review, we therefore define g_s as the maximum measured value of water vapour passage through the stomata. Nearly all the water transpired by plants is lost through the stomata as water vapour diffusion via cuticle can be neglected. Methods applied for determining the diffusive conductance include porometer and photosynthesis cuvette measurements as well as energy balancing approaches (e.g. Körner et al., 1979;

Table 3
Minimum and maximum albedo—a_{min}/a_{max}

a_{min}	a_{max}	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
Crops														
0.16	0.25	*Avena sativa*											USA, AZ	Fritschen (1967)
0.24	0.24	*Avena sativa*											n.d.	Impens and Lemeur (1969)
0.18	0.22	*Beta vulgaris*											n.d.	Kondratyev (1969)
0.25	0.25	*Beta vulgaris*											n.d.	Monteith (1959) in Iqbal (1983)
0.19	0.28	*Brassica oleracea acephale*											UK	Monteith and Szeicz (1961)
0.21	0.27	*Capsicum annuum*											n.d.	Gates (1980)
0.20	0.20	*Glycine max*									43N	1W	FR	Goutorbe (1991) in Calvet et al. (1998)
0.22	0.22	*Glycine max*	Late season								44N	5E	FR	Olioso et al. (1996) in Calvet et al. (1998)
0.21	0.32	*Helianthus annuus*											n.d.	Gates (1980)
0.23	0.29	*Helianthus annuus*											n.d.	Gates (1980)
0.28	0.28	*Helianthus annuus*											n.d.	Impens and Lemeur (1969)
0.20	0.26	*Hordeum vulgare*											USA, AZ	Fritschen (1967)
0.23	0.26	*Hordeum vulgare*											n.d.	Monteith and Unsworth (1990)
0.23	0.23	*Lycopersicon lycopersicum*											n.d.	Monteith and Unsworth (1990)
0.24	0.24	*Nicotiana tabacum*											n.d.	Monteith and Unsworth (1990)
0.23	0.23	*Phaesolus* spp.											n.d.	Impens and Lemeur (1969)
0.24	0.24	*Phaesolus* spp.											n.d.	Monteith and Unsworth (1990)
0.11	0.18	*Secale cereale*											n.d.	Kondratyev (1972)
0.21	0.21	*Secale cereale*											n.d.	Kondratyev (1969)
0.10	0.25	*Secale cereale, Triticum aestivum*											n.d.	Budyko (1974)
0.15	0.25	*Solanum tuberosum*											n.d.	Budyko (1974)
0.19	0.22	*Sorghum* spp.											USA, AZ	Fritschen (1967)
0.10	0.25	*Triticum aestivum*											n.d.	Kondratyev (1969)
0.13	0.21	*Triticum aestivum*											n.d.	Kondratyev (1972)
0.18	0.23	*Triticum aestivum*											USA, AZ	Fritschen (1967)
0.20	0.23	*Triticum aestivum*											USA, IL	Song (1998)
0.22	0.26	*Triticum aestivum*											n.d.	Monteith and Unsworth (1990)

Table 3 (*Continued*)

a_{min}	a_{max}	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
0.16	0.23	*Zea mays*											n.d.	Kondratyev (1972)
0.18	0.22	*Zea mays*											n.d.	Monteith and Unsworth (1990)
0.18	0.22	*Zea mays*									52N	5E	NL	Jacobs and van Pul (1990)
0.20	0.20	*Zea mays*									43N	1E	FR	Cabelguenne et al. (1990) in Calvet et al. (1998)
0.20	0.26	*Zea mays*											USA, IL	Song (1998)
0.25	0.25	*Zea mays*											n.d.	Impens and Lemeur (1969)
0.10	0.25	n.d.	Crops										n.d.	Budyko (1956) in Rutter (1968)
0.20	0.20	n.d.	Crops										n.d.	Baumgartner (1967) in Rutter (1968)
0.24	0.25	n.d.	Crops										UK	Barry and Chambers (1966) in Rutter (1968)
Herbs, forbs, grasses														
0.22	0.28	*Aristida* spp.											n.d.	Gates (1980)
0.22	0.28	*Aristida* spp.											n.d.	Gates (1980)
0.21	0.26	*Clematis fremontii*											n.d.	Gates (1980)
0.02	0.05	*Medicago sativa*											n.d.	Ashburn and Weldon (1956) in Iqbal (1983)
0.20	0.27	*Medicago sativa*											USA, AZ	Fritschen (1967)
0.31	0.38	*Parmelia* spp.											n.d.	Gates (1980)
0.23	0.29	*Parthenium integrifolium*											n.d.	Gates (1980)
0.22	0.28	*Pelargonium* spp.											n.d.	Gates (1980)
0.17	0.22	*Reboulia* spp.											n.d.	Gates (1980)
0.05	0.14	*Schizachyrium scoparium, Bouteloua* spp.						14.2	1166	350	36N	96W	USA, OK	Burba and Verma (2001)
0.23	0.29	*Streliztsia* spp.											n.d.	Gates (1980)
0.36	0.42	*Verbascum* spp.											n.d.	Gates (1980)
0.23	0.29	*Xanthium* spp.											n.d.	Gates (1980)
0.23	0.29	*Xanthium* spp.											n.d.	Gates (1980)
0.14	0.37	n.d.	Grass										n.d.	List (1966) in Iqbal (1983)
0.15	0.25	n.d.	Grass										n.d.	Budyko (1956) in Rutter (1968)
0.22	0.26	n.d.	Grass										UK	Barry and Chambers (1966) in Rutter (1968)

0.22	0.33	n.d.	Grass								n.d.	Angstrom (1925) in Rutter (1968)
0.25	0.25	n.d.	Grass						52N	5E	NL	Chen et al. (1997) in Calvet et al. (1998)
0.14	0.24	n.d.	Pasture					548			AT	Rosset et al. (1997)
0.14	0.24	n.d.	Pasture					915			AT	Rosset et al. (1997)
0.14	0.24	n.d.	Pasture					1367			AT	Rosset et al. (1997)
0.15	0.25	n.d.	Meadow								n.d.	Budyko (1974)
0.20	0.20	n.d.	Fallow						43N	1E	FR	Bessemoulin et al. (1996) in Calvet et al. (1998)
0.23	0.28	n.d.	Short-long grass								UK	Monteith and Szeicz (1961)
0.15	0.22	n.d.	Tallgrass prairie								n.d.	Song (1998)
0.20	0.27	n.d.	Semiarid grass						34S	145E	AU	Grant et al. (2000)
0.20	0.30	n.d.	Dry steppe								n.d.	Budyko (1974)
Shrubs, woodland												
0.33	0.38	*Andromeda glaucophylla*									n.d.	Gates (1980)
0.37	0.44	*Artemisia* spp.									n.d.	Gates (1980)
0.10	0.10	*Calluna* spp.									n.d.	Kondratyev (1969)
0.30	0.37	*Chamaedaphne calyculata*									n.d.	Gates (1980)
0.33	0.40	*Kalmia polifolia*									n.d.	Gates (1980)
0.16	0.16	n.d.	Coniferous								n.d.	Monteith and Unsworth (1990)
0.18	0.18	n.d.	Deciduous								n.d.	Monteith and Unsworth (1990)
Coniferous trees												
0.05	0.06	*Picea abies*									n.d.	Tajchman (1967, 1972a) in Jarvis et al. (1976)
0.09	0.09	*Pinus contorta*									n.d.	Gay (1971)b in Jarvis et al. (1976)
0.14	0.20	*Pinus halepensis*									n.d.	Stanhill (1970) in Jarvis et al. (1976)
0.17	0.17	*Pinus halepensis*									n.d.	Monteith and Unsworth (1990)
0.10	0.10	*Pinus radiata*									n.d.	Denmead (1969) in Jarvis et al. (1976)
0.07	0.15	*Pinus sylvestris*		125	15.6	15.0	400	185	60N	16E	SE	Perttu et al. (1980)
0.08	0.08	*Pinus sylvestris*									n.d.	Stewart (1971); Gay and Stewart (1973) in Jarvis et al. (1976)

Table 3 (*Continued*)

a_{min}	a_{max}	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei	Lat	Lon	Country	Source
0.11	0.11	*Pinus taeda*											n.d.	Gay and Knoerr (1970); Gay (1971a) in Jarvis et al. (1976)
0.09	0.09	*Pseudotsuga menziesii*											n.d.	Gay (1972); Gay and Stewart (1973) in Jarvis et al. (1976)
0.10	0.14	n.d.	Forest										n.d.	Angstrom (1925) in Rutter (1968)
0.10	0.15	n.d.	Forest										n.d.	Budyko (1956) in Rutter (1968)
0.10	0.15	n.d.	Forest										n.d.	Budyko (1974)
0.11	0.11	n.d.	Forest										n.d.	Baumgartner (1967) in Rutter (1968)
0.12	0.12	n.d.	Forest										n.d.	Conover (1965) in Iqbal (1983)
0.12	0.13	n.d.	Forest										n.d.	Stanhill (1966) in Rutter (1968)
0.15	0.20	n.d.	Forest										UK	Barry and Chambers (1966) in Rutter (1968)
0.11	0.23	n.d.	Tundra										n.d.	List (1966) in Iqbal (1983)
0.15	0.20	n.d.	Tundra										n.d.	Budyko (1974)
0.10	0.19	n.d.	Coniferous, deciduous										n.d.	List (1966) in Iqbal (1983)
Deciduous trees														
0.22	0.27	*Acer saccharinum*											n.d.	Gates (1980)
0.11	0.17	*Acer sacchanum. Liriodendron tulipifera, Sassafras albidum, Quercus alba, Quercus nigra*	Annual measurements		26.0	26.3				275	39N	86W	USA, IN	Schmid et al. (2000)
0.23	0.30	*Aesculus hippocastanum*											n.d.	Gates (1980)
0.22	0.28	*Ailanthus altissima*											n.d.	Gates (1980)
0.30	0.33	*Betula* spp.											n.d.	Monteith and Unsworth (1990)
0.09	0.28	*Betula* spp.-*Populus* spp.		45	16.0								RU	Rauner (1976)
0.24	0.30	*Carya* spp.											n.d.	Gates (1980)
0.21	0.26	Cercis canadensis											n.d.	Gates (1980)

0.24	0.31	*Colocasia* spp.										n.d.	Gates (1980)
0.23	0.30	*Erythrina* spp.										n.d.	Gates (1980)
0.26	0.32	*Euonymus bungeanus*										n.d.	Gates (1980)
0.23	0.29	*Fagus grandifolia*										n.d.	Gates (1980)
0.20	0.26	*Fagus sylvatica*										n.d.	Gates (1980)
0.27	0.33	*Ginko biloba*										n.d.	Gates (1980)
0.21	0.27	*Hamamelis venalis*										n.d.	Gates (1980)
0.24	0.29	*Liriodendron tulipifera*										n.d.	Gates (1980)
0.20	0.25	*Magnolia virginiana*										n.d.	Gates (1980)
0.23	0.28	*Platanus occidentalis*										n.d.	Gates (1980)
0.23	0.28	*Populus deltoides*										n.d.	Gates (1980)
0.28	0.33	*Populus* spp.										n.d.	Monteith and Unsworth (1990)
0.25	0.31	*Prunus persica*										n.d.	Gates (1980)
0.24	0.30	*Prunus serotina*										n.d.	Gates (1980)
0.23	0.29	*Quercus alba*										n.d.	Gates (1980)
0.22	0.28	*Quercus imbricaria*										n.d.	Gates (1980)
0.21	0.26	*Quercus macrocarpa*										n.d.	Gates (1980)
0.25	0.31	*Quercus marilandica*										n.d.	Gates (1980)
0.11	0.19	*Quercus rubra, Acer rubrum*		20.0					315	43N	72W	USA, MA	Sakai et al. (1997)
0.10	0.20	*Quercus* spp.		9.5								BE	Grulois (1968) in Rauner (1976)
0.32	0.36	*Quercus* spp.										n.d.	Monteith and Unsworth (1990)
0.23	0.29	*Quercus velutina*										n.d.	Gates (1980)
0.11	0.19	*Quercus-Carpinus*										BE	Grulois (1968)
0.23	0.29	*Sassafras albidum*										n.d.	Gates (1980)
0.24	0.31	*Ulmus* spp.										n.d.	Monteith and Unsworth (1990)
0.15	0.20	n.d.	Forest									n.d.	Budyko (1974)
0.15	0.20	n.d.	Broadleaved									n.d.	Budyko (1956) in Rutter (1968)
0.16	0.23	n.d.	Broadleaved									n.d.	Stanhill (1966) in Rutter (1968)
0.17	0.19	n.d.	Broadleaved									UK	Barry and Chambers (1966) in Rutter (1968)
0.18	0.18	n.d.	Broadleaved									n.d.	Angstrom (1925) in Rutter (1968)

a_{min}/a_{max}—minimum and maximum value for albedo. Sci. name: scientific names for species were taken as published by authors and not transformed into current nomenclature, n.d.: no details given; Furth. Inf.: further information given in literature; PlaH: plant height (m); BasA: basal area ($m^2\ ha^{-1}$); StoD: stock density (ha^{-1}); MAT: mean annual temperature (°C); MAP: mean annual precipitation (mm); Hei: height above sea level (m); Lat: latitude (°); Lon: longitude (°); Country: abbreviation of countries follows ISO 3166.

Falge et al., 1996; Niklaus et al., 1998). Stomatal conductance is given in (mm s^{-1}). In cases where stomatal conductance is published in (mmol m^{-2}) values were divided by 41 for transformation according to Körner et al. (1979, calculation based on 293 K and 10^5 Pa).

Many values in Table 4 for stomatal conductance are cited from Körner et al., who published a comprehensive review in "1979". Additional values for stomatal conductance according to typical plant species in temperate land use systems evaluated by other authors are taken into account in Table 4 (e.g. Lu et al., 1995; Bunce, 2000). Woody plants reveal general lower stomatal conductance of 2.5–4.0 mm s^{-1} compared to herbal plants species with around 6 mm s^{-1} (Table 7). Spans of published data for these herbal plant species are broad, indicated by comparatively high standard deviation with approximately 4 mm s^{-1} for crops and 6 mm s^{-1} for herbs, forbs and grasses.

Presenting single values for g_s neglects its high temporal (especially daily) and spatial variability. Thus, in some ways it is difficult to compare published data as investigations under natural conditions are strongly affected by factors such as water vapour pressure deficit, soil moisture, general conditions of the plant (healthy/unhealthy), position of leaves or needles (shaded/exponated), age of leaves or needles. Nevertheless, many SVAT (Soil-Vegetation-Atmosphere Transfer) and hydrological models need single g_s values as input parameters. Data for g_s was therefore taken as published or read of graphs. The mean value for g_s in a given land cover type—if data for g_s are significantly normal distributed—reflects a sufficient approximation of natural conditions, as it averages information over space, time and species.

2.5. Maximum plant height—H_{max}

Maximum plant height is one of the main parameters for calculating the above ground biomass, nutrient balances or carbons sequestration potentials of a given site. In hydrology, the maximum plant height H_{max} is used to determine the aerodynamic resistance of the vegetation which in turn may be used to calculate the potential evapotranspiration.

Typical values for maximum plant height of pasture species are adopted from Ellenberg (1996) and Geyger (1964) whereas information for crops are taken from Rothmaler (1990). Further maximum plant heights for herbaceous plants are given in most plant handbooks. As it does not make sense to list all plant species of Europe and North America in this context, a set of typical mid European species is chosen (Table 5). In most cases of ecological and hydrological modelling approaches these values can be used for North American ecosystems as well, as there is not much of a difference in maximum heights for herbs, forbs, grasses and crops in global temperate regions.

In contrast to low-growing plants where set values for maximum plant height make sense—even though they can vary considerably (Table 7)—absolute dimensions of coniferous and deciduous trees are far more higher and diverse. Exact parameter setting of maximum tree height for forests can therefore be most important to obtain good results in biomass production or evapotranspiration rates. Hence, in micro- and mesoscale modelling values for H_{max} should be obtained from regionally adapted forest growth tables, where site conditions, size classes, and stand age are considered. Plant height for grain crops in most cases does not exceed 2.0 m, whereas some species like *Helianthus annuus* or *Phaseolus* spp. grow up to 4.0 and 5.0 m, respectively (Table 5). Wetland species like *Phragmites communis* show H_{max} of up to 3.0 m, whereas other herbaceous plants and grasses show an average H_{max} of 1.0–1.2 m. An overall mean for H_{max} of pasture species (1.4 m)—no matter whether wetland or dryland species—is equivalent to mean H_{max} of crops (Table 7).

2.6. Maximum rooting depth—RD_{max}

The rooting depth of plants determines the maximum depth of water and nutrient uptake from the soil profile. Maximum root depth RD_{max} depends mainly on soil factors like texture, compaction, underlying bedrock, clefts, and further physical and chemical properties of the solum. Sites where soil layers such as clay bands prevent vertical water flow, or groundwater is close to surface, are not suitable for deep rooting plants as anoxic areas impede conditions for root growth. Depth of tree roots is further defined by the root shape. Tap roots of trees generally grow further into the soil compared to plate or heart shaped root systems. To take these restrictions into account, available information of soil conditions is also presented in Table 6 in addition.

Table 4
Stomatal conductance—g_s

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
Crops													
2.3	*Alocasia indica*											n.d.	Raschke (1958) in Körner et al. (1979)
5.6	*Beta vulgaris*											GRH	Hall and Kaufmann (1975a) in Körner et al. (1979)
7.1	*Beta vulgaris*		4 w									GRH	Hansen (1971) in Körner et al. (1979)
10.0	*Beta vulgaris*								600			AT	Scheel (unpubl.) in Körner et al. (1979)
3.3	*Cucumus sativus*		4 w									GRH	Behboudian (1977) in Körner et al. (1979)
4.3	*Dolichos uniflorus*											GRH	Ludlow and Wilson (1971b) in Körner et al. (1979)
3.3	*Glycine max*											GRH	Sionit and Kramer (1976) in Körner et al. (1979)
6.7	*Glycine max*		26–46 d									GRH	Woodward and Begg (1976) in Körner et al. (1979)
7.1	*Glycine max*	4th leaf	10–20 d									GRH	Woodward and Rawson (1976) in Körner et al. (1979)
2.1	*Glycine max*	Potted plants										USA, OH	Mederski et al. (1975) in Körner et al. (1979)
16.1	*Glyceria max*	Low p_{H_2O}										GRH	Bunce (1985)
6.7	*Glycine wightii*											GRH	Körner et al. (1979)
1.5	*Helianthus annuus*		8 w									USA, NY	Hunt et al. (1968) in Körner et al. (1979)
2.5	*Helianthus annuus*											GRH	Holmgren et al. (1965) in Körner et al. (1979)
3.3	*Helianthus annuus*		2 mth									GRH	Sionit and Kramer (1976) in Körner et al. (1979)
7.7	*Helianthus annuus*		8 w									GRH	Aston (1973) in Körner et al. (1979)
15.9	*Helianthus annuus*											GRH	Schurr et al. (1992)
23.8	*Helianthus annuus*											GRH	Holmgren et al. (1965)
7.1	*Helianthus annuus*	4–6 leaves										GRH	Hall and Kaufmann (1975a) in Körner et al. (1979)
7.1	*Helianthus annuus*	6–8 leaves										GRH	Aston (1976) in Körner et al. (1979)
12.5	*Helianthus annuus*	14th leaf										GRH	Rawson and Woodward (1976) in Körner et al. (1979)
16.7	*Helianthus annuus*	Low soil H_2O										GRH	Gollan et al. (1986)
4.0	*Hordeum distichum*											UK	Day (1977)

Table 4 (*Continued*)

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
4.2	*Hordeum distichum*											UK	Monteith et al. (1965) in Körner et al. (1979)
4.0	*Hordeum distichum*											UK	Day (1977)
4.2	*Hordeum distichum*											UK	Monteith et al. (1965)
5.0	*Hordeum vulgare*											GRH	Jones (1977)
5.6	*Hordeum vulgare*											GRH	Jones (1977)
7.0	*Hordeum vulgare*											USA, MD	Bunce (2000)
8.3	*Hordeum vulgare*											GRH	Cummins et al. (1971) in Körner et al. (1979)
2.5	*Lactuca sativa*											GRH	Tibbitts and Bottenberg (1976) in Körner et al. (1979)
4.0	*Lycopersicum esculentum*			0.3								GRH	Moreshet and Yocum (1972) in Körner et al. (1979)
7.7	*Lycopersicum esculentum*											n.d.	Duniway (1971) in Körner et al. (1979)
4.8	*Nicotiana tabacum*											USA, CT	Turner and Begg (1973) in Körner et al. (1979)
11.1	*Nicotiana tabacum*	12th leaf										GRH	Rawson and Woodward (1976) in Körner et al. (1979)
5.3	*Phaseolus vulgaris*											USA, WI	Kanemasu et al. (1969)
7.7	*Phaseolus vulgaris*		12 d									GRH	Charter et al. (1970) in Körner et al. (1979)
7.7	*Phaseolus vulgaris*											GRH	Moldau (1973) in Körner et al. (1979)
3.7	*Phaseolus vulgaris*	1st leaf	10–14 d									GRH	Solárova et al. (1977) in Körner et al. (1979)
10.0	*Secale cereale*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
5.0	*Solanum tuberosum*		3–12 w									AU	Shepherd (1976) in Körner et al. (1979)
2.3	*Sorghum bicolor*		m									USA, CT	Turner and Begg (1973) in Körner et al. (1979)
3.4	*Sorghum bicolor*											GRH	Henzell et al. (1976) in Körner et al. (1979)
2.8	*Sorghum bicolor*	15 leaves										GRH	Beardsell and Cohen (1975) in Körner et al. (1979)
5.0	*Triticum aestivum*		3–6 mth									AU	Shepherd (1976) in Körner et al. (1979)

5.6	*Triticum aestivum*		1 mth			GRH	Simmelsgaard (1976) in Körner et al. (1979)
10.4	*Triticum aestivum*					USA, MD	Bunce (2000)
12.6	*Triticum aestivum*	Low soil H_2O				GRH	Gollan et al. (1986)
9.1	*Triticum vulgare*				580	AT	Scheel (unpubl.) in Körner et al. (1979)
1.0	*Vitis vinifera*		1			GRH	Hofäcker (1976) in Körner et al. (1979)
1.5	*Vitis vinifera*		1			n.d.	Düring (1976a) in Körner et al. (1979)
2.7	*Vitis vinifera*					GRH	Loveys et al. (1974) in Körner et al. (1979)
2.9	*Vitis vinifera*				400	IT	Scheel (unpubl.) in Körner et al. (1979)
2.9	*Vitis vinifera*				400	IT	Körner et al. (1979)
4.5	*Vitis vinifera*				400	IT	Körner et al. (1979)
1.5	*Vitis vinifera*	Cuttings				GRH	Hofäcker (1976) in Körner et al. (1979)
3.1	*Vitis vinifera*	5–6 leaves				GRH	Düring (1976b) in Körner et al. (1979)
2.3	*Zea mays*			1.5		USA, CT	Turner (1975) in Körner et al. (1979)
5.9	*Zea mays*					NL	Stigter and Lammers (1974) in Körner et al. (1979)
6.3	*Zea mays*				580	AT	Scheel (unpubl.) in Körner et al. (1979)
7.1	*Zea mays*					n.d.	Sinclair et al. (1975) in Körner et al. (1979)
3.1	*Zea mays*	7–9 leaves				GRH	Dubé et al. (1974) in Körner et al. (1979)
Herbs, forbs, grasses							
26.3	*Abutilon theophrasti*	Low p_{H_2O}				GRH	Bunce (1985)
2.4	*Agropyron desertorum*					GRH	Frank et al. (1976) in Körner et al. (1979)
1.4	*Agropyron intermedium*					GRH	Frank et al. (1976) in Körner et al. (1979)
8.3	*Agropyron smithii*					GRH	Frank et al. (1976) in Körner et al. (1979)
2.5	*Alium ursinum*				580	AT	Scheel (unpubl.) in Körner et al. (1979)
6.7	*Alopecurus pratensis*	2nd leaf				CZ/SK	Gloser (1976) in Körner et al. (1979)
5.6	*Alopecurus pratensis*	4th leaf				CZ/SK	Gloser (1976) in Körner et al. (1979)

Table 4 (*Continued*)

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
7.7	*Arrhenatherum elatius*								650			AT	Cernusca (1975) in Körner et al. (1979):
3.3	*Asarum europeum*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
6.7	*Astrebla lappacea*											GRH	Doley and Yates (1976) in Körner et al. (1979)
11.0	*Atriplex hastata*											GRH	Slatyer (1970) in Körner et al. (1979)
3.8	*Atriplex spongiosa*											GRH	Slatyer (1970) in Körner et al. (1979)
7.1	*Brachiaria ruziziensis*	Tiller										GRH	Ludlow and Wilson (1971)b in Körner et al. (1979)
1.2	*Brachipodium pinnatum*								201	48N	7E	DE	Wedler et al. (1996)
3.3	*Brassica rapa*											GRH	Gaastra (1959) in Körner et al. (1979)
12.5	*Bromus erectus*											CH	Niklaus et al. (1998)
2.5	*Bromus inermis*											USA, NH	Lea et al. (1977) in Körner et al. (1979)
10.0	*Caltha leptosepala*											USA, CO	Ehleringer and Miller (1975) in Körner et al. (1979)
7.7	*Caltha palustris*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
3.2	*Carex alba*								201	48N	7E	DE	Wedler et al. (1996)
2.0	*Carex aquatilis*											GRH	Johnson and Caldwell (1975) in Körner et al. (1979)
8.3	*Carex bigelowii*											USA, NH	Curtin and Mayo (1975) in Körner et al. (1979)
5.0	*Carex curvula*								2300			AT	Körner (1977) in Körner et al. (1979)
3.2	*Carex flacca*								201	48N	7E	DE	Wedler et al. (1996)
5.3	*Cenchrus ciliaris*											GRH	Ludlow and Wilson (1971b) in Körner et al. (1979)
0.8	*Circea lutetiana*											GRH	Holmgren et al. (1965)
12.5	*Convolvulus arvensis*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
6.7	*Coronilla varia*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
2.5	*Dactylis glomerata*											GRH	Frank et al. (1976) in Körner et al. (1979)

6.7	*Dactylis glomerata*			650			AT	Körner et al. (1979)
33.1	*Datura stramonium*	Low p_{H2O}					GRH	Bunce (1985)
4.0	*Deschampsia cespitosa*						GRH	Johnson and Caldwell (1975) in Körner et al. (1979)
2.1	*Diapensia lapponica*						USA, NH	Courtin and Mayo (1975) in Körner et al. (1979)
6.3	*Diplotaxis tenufolia*			580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.8	*Dupontia fischeri*						GRH	Johnson and Caldwell (1975) in Körner et al. (1979)
6.3	*Elymus junceuns*						GRH	Frank et al. (1976) in Körner et al. (1979)
3.3	*Festuca halleri*			2300			AT	Körner et al. (1979)
3.0	*Gentiana punctata*			1800			AT	Körner and Schubert (1978) in Körner et al. (1979)
10.0	*Geum montanum*			1800			AT	Körner and Schubert (1978) in Körner et al. (1979)
3.0	*Geum rosii*						GRH	Johnson and Caldwell (1975) in Körner et al. (1979)
5.6	*Glyceria maxima*	2nd leaf					CZ/SK	Gloser (1976) in Körner et al. (1979)
6.7	*Glyceria maxima*	4th leaf					CZ/SK	Gloser (1976) in Körner et al. (1979)
5.3	*Hieracium alpinum*			2300			AT	Körner (1977) in Körner et al. (1979)
6.3	*Holcus lanatus*			650			AT	Körner et al. (1979)
5.9	*Impatiens parviflora*			580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.1	*Lamium galeobdolon*						GRH	Holmgren et al. (1965)
2.5	*Lolium perenne*						GRH	Sheehy et al. (1975) in Körner et al. (1979)
6.3	*Luzula sylvatica*			1800			AT	Körner and Schubert (1978) in Körner et al. (1979)
3.3	*Melinis minutiflora*						GRH	Ludlow and Wilson (1971)b in Körner et al. (1979)
29.2	*Moliniopsis japonica*	Mire wetland	1049	6.5	45N	141E	JP	Takagi et al. (1998)
1.2	*Oxalis acetosella*			580			AT	Scheel (unpubl.) in Körner et al. (1979)
4.2	*Paeonia officinalis*			580			AT	Scheel (unpubl.) in Körner et al. (1979)
3.8	*Panicum coloratum*						GRH	Ludlow and Wilson (1971b) in Körner et al. (1979)

Table 4 (*Continued*)

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
11.1	*Panicum maximum*											GRH	Ludlow and Wilson (1972) in Körner et al. (1979)
14.3	*Pennisetum purpureum*											GRH	Ludlow and Wilson (1972) in Körner et al. (1979)
1.5	*Phalaris arundinacea*											GRH	Frank et al. (1976) in Körner et al. (1979)
6.3	*Phalaris arundinacea*	2nd leaf										CZ/SK	Gloser (1976) in Körner et al. (1979)
5.6	*Phalaris arundinacea*	4th leaf										CZ/SK	Gloser (1976) in Körner et al. (1979)
3.6	*Phyllitis scolopendrium*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
12.5	*Polygonum bistortoides*								3550			USA, CO	Ehleringer and Miller (1975) in Körner et al. (1979)
2.8	*Prenanthes purpurea*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
6.7	*Primula minima*								2300			AT	Körner (1977) in Körner et al. (1979)
2.8	*Pulmonaria officinalis*								580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.7	*Rhus integrifolia*											USA, CA	Poole and Miller (1975) in Körner et al. (1979)
4.2	*Rhus integrifolia*											USA, CA	Poole and Miller (1975) in Körner et al. (1979)
1.5	*Rhus ovata*											USA, CA	Poole and Miller (1975) in Körner et al. (1979)
3.7	*Rumex alpestris*								1900			AT	Körner et al. (1979)
10.0	*Rumex alpinus*								1800			AT	Körner and Schubert (1978) in Körner et al. (1979)
1.2	*Sedum rupestre*								660			AT	Körner et al. (1979)
1.8	*Sesleria caerulea*											GRH	Lloyd and Woolhouse (1976) in Körner et al. (1979)
3.7	*Setaria sphacelata*											GRH	Ludlow and Wilson (1971b) in Körner et al. (1979)
1.7	*Solidago virgaurea*	Shaded										GRH	Holmgren (1968) in Körner et al. (1979)
2.1	*Solidago virgaurea*	Exposed										GRH	Holmgren (1968) in Körner et al. (1979)
6.7	*Sorghum almum*											GRH	Ludlow and Wilson (1972) in Körner et al. (1979)

5.9	*Stachys recta*					580			AT	Scheel (unpubl.) in Körner et al. (1979)
2.5	*Stellaria nemorum*					1800			AT	Körner and Schubert (1978) in Körner et al. (1979)
6.5	*Trifolium pratense*					650			AT	Cernusca (1975) in Körner et al. (1979)
5.6	*Veratrum album*					1800			AT	Körner and Schubert (1978) in Körner et al. (1979)
3.4	*Vicia sepium*					580			AT	Scheel (unpubl.) in Körner et al. (1979)
5.9	*Xanthium pennsylvanicum*	Potted plants							n.d.	Mellor et al. (1964) in Körner et al. (1979)
10.0	*Xanthium strumarium*								GRH	Drake and Raschke (1974) in Körner et al. (1979)
25.0	*Xanthium strumarium*		60 d						n.d.	Drake et al. (1970) in Körner et al. (1979)
Shrubs, woodland										
1.0	*Artemisia tridentata*								USA, UT	De Puit and Caldwell (1975) in Körner et al. (1979)
6.6	*Eucalyptus pauciflora*	Sclerophyll		11.5	650	940	37S	149E	AU	Körner and Cochrane (1985)
8.5	*Eucalyptus pauciflora*	Subalpine				1645	37S	149E	AU	Körner and Cochrane (1985)
2.3	*Hedera helix*								GRH	Bauer (unpubl.) in Körner et al. (1979)
2.6	*Heteromeles arbutifolia*								USA, CA	Poole and Miller (1975) in Körner et al. (1979)
3.1	*Heteromeles arbutifolia*								USA, CA	Poole and Miller (1975) in Körner et al. (1979)
17.9	*Ilex crenata*	Mire wetland			1049	7	45N	141E	JP	Takagi et al. (1998)
3.3	*Ligustrum vulgare*					600			AT	Scheel (unpubl.) in Körner et al. (1979)
3.2	*Loiseleuria procumbens*		6–8			2175			AT	Körner (1976) in Körner et al. (1979)
37.5	*Myrica gale*	Mire wetland			1049	7	45N	141E	JP	Takagi et al. (1998)
5.0	*Physocarpus malvaceus*								USA, ID	Cline and Campbell (1976) in Körner et al. (1979)
1.7	*Physocarpus opulifolius*		4 mth						GRH	Pereira and Kozlowski (1977)
7.4	*Quercus myrtifolia*				1310		28N	80W	USA, FL	Lodge et al. (2001)
5.3	*Rosmarinus officinalis*	Potted plants	10						GRH	Körner et al. (1979)
10.0	*Ruta graveolens*					580			AT	Scheel (unpubl.) in Körner et al. (1979)

Table 4 (*Continued*)

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
23.2	*Sasa palmata*	Mire wetland						1049	7	45N	141E	JP	Takagi et al. (1998)
1.9	*Vaccinium myrtillus*	Understory							900			AT	Scheel (unpubl.) in Körner et al. (1979)
1.3	*Vaccinium myrtillus*	Shade leaves										USA, CO	Janke (1970) in Körner et al. (1979)
2.3	*Vaccinium myrtillus*	Sun leaves										USA, CO	Janke (1970) in Körner et al. (1979)
2.6	*Vaccinium myrtillus*	Timberline							2000			AT	Scheel (unpubl.) in Körner et al. (1979)
Coniferous trees													
2.2	*Abies amabilis*	New needles	43	14.6	78.7	1941			1300			USA, WA	Martin et al. (1997)
1.5	*Abies amabilis*	5 yr needles	43	14.6	78.7	1941			1300			USA, WA	Martin et al. (1997)
1.9	*Abies grandis*			2.0					700			USA, OR	Running (1976) in Körner et al. (1979)
4.8	*Abies magnifica*			2.0					1200			USA, OR	Running (1976) in Körner et al. (1979)
2.7	*Abies procera*			2.0					1000			USA, OR	Running (1976) in Körner et al. (1979)
0.8	*Juniperus virginiana*			7.0					580			AT	Körner et al. (1979)
2.4	*Larix* x *eurolepis*											GRH	Sandford and Jarvis (1986)
0.5	*Picea abies*		30	12.6	45.9	2343	6	1500	1050	48N	7E	FR	Lu et al. (1995)
1.2	*Picea abies*		120	30.0				1070	685			CH	Falge et al. (1996)
1.8	*Picea abies*		40					1200	700			CH	Falge et al. (1996)
0.7	*Picea abies*	Healthy	30	12.0					680	50N	11E	DE	Zimmermann et al. (1988)
1.5	*Picea abies*	Healthy	30	10.0	32.3	3100						DE	Oren and Zimmermann (1989)
1.8	*Picea abies*	Declining	30	12.0					750	50N	11E	DE	Zimmermann et al. (1988)
1.9	*Picea abies*	Declining	30	7.9	26.8	4400						DE	Oren and Zimmermann (1989)
2.8	*Picea breweriana*			2.0					1200			USA, OR	Running (1976) in Körner et al. (1979)
1.7	*Picea engelmannii*		15						3000			USA, CO	Kaufmann (1976) in Körner et al. (1979)
1.2	*Picea mariana*		75	10.5		750				56N	99W	CA	Dang et al. (1997)
2.0	*Picea sitchensis*			2.0					200			USA, OR	Running (1976) in Körner et al. (1979)
6.9	*Picea sitchensis*											GRH	Sandford and Jarvis (1986)
3.8	*Picea sitchensis*	Seedlings	7 mth									GRH	Grace et al. (1975) in Körner et al. (1979)
4.0	*Picea sitchensis*	Seedlings	2									GRH	Braddle and Jarvis (1977) in Körner et al. (1979)
3.8	*Picea sitchensis*	New needles		11.5					280			UK	Watts et al. (1976) in Körner et al. (1979)

1.8	*Picea sitchensis*	1 yr needles		11.5				280			UK	Watts et al. (1976) in Körner et al. (1979)
2.0	*Pinus banksiana*		58	9		2488			56N	99W	CA	Dang et al. (1997)
2.0	*Pinus banksiana*		8								USA, WI	Pereira and Kozlowski (1977b) in Körner et al. (1979)
2.9	*Pinus banksiana*		82	13.5	21.9	1875		579	54N	104W	CA	Saugier et al. (1997)
1.2	*Pinus cembra*	1 yr needles		8.0				1900			AT	Scheel (unpubl.) in Körner et al. (1979)
1.5	*Pinus cembra*	New needles		8.0				1900			AT	Scheel (unpubl.) in Körner et al. (1979)
4.0	*Pinus contorta*		60					2800			USA, WY	Lassoie et al. (1977) in Körner et al. (1979)
6.9	*Pinus contorta*										GRH	Sandford and Jarvis (1986)
1.1	*Pinus monticola*			25.0							USA, ID	Cline and Campbell (1976) in Körner et al. (1979)
4.0	*Pinus pinaster*		64	24.1	29.8	312	550	24	39N	9W	PT	Loustau et al. (1996)
2.3	*Pinus pinaster*	New needles	37	20.3	21.8	385		146	44N	1W	FR	Granier et al. (1990)
3.0	*Pinus pinaster*	New needles	37	20.3	21.8	385		146	44N	1W	FR	Granier et al. (1990)
2.2	*Pinus pinaster*	2 yr needles	37	20.3	21.8	385		146	44N	1W	FR	Granier et al. (1990)
3.2	*Pinus ponderosa*			2.0				1150			USA, OR	Running (1976) in Körner et al. (1979)
3.2	*Pinus ponderosa*	Seedlings	5	1							GRH	Hubbard et al. (2001)
0.8	*Pinus ponderosa*	New needles	24								USA, CA	Bingham and Coyne (1977) in Körner et al. (1979)
2.0	*Pinus ponderosa*	1 yr needles	24								USA, CA	Bingham and Coyne (1977) in Körner et al. (1979)
2.0	*Pinus resinosa*		9								USA, WI	Raschke, 1958 in Körner et al. (1979)
1.4	*Pinus resinosa*	New needles									USA, CT	Waggoner and Turner (1971) in Körner et al. (1979)
0.6	*Pinus resinosa*	1 yr needles									USA, CT	Waggoner and Turner (1971) in Körner et al. (1979)
2.5	*Pinus resinosa*	1 yr needles		16.0				500			USA, WI	Pereira and Kozlowski (1976)a in Körner et al. (1979)
5.1	*Pinus sylvestris*										GRH	Sandford and Jarvis (1986)
7.4	*Pinus sylvestris*										GRH	Sandford and Jarvis (1986)
1.6	*Pinus sylvestris*	New needles		20.0				580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.5	*Pinus sylvestris*	1 yr needles		20.0				580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.7	*Pinus sylvestris*	1 yr needles		15.0				1000			AT	Körner et al. (1979)
4.0	*Pinus taeda*		16								USA, NC	Gresham et al. (1975)
1.7	*Pseudotsuga menziesii*			2.0				700			USA, OR	Blake and Ferrell (1977) in Körner et al. (1979)

Table 4 (*Continued*)

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
3.3	*Pseudotsuga menziesii*	Seedlings	2									GRH	Running (1976) in Körner et al. (1979)
2.1	*Taxodium distichum*		64	27	73.6	722	15.5	1140	130	35N	79W	USA, NC	Oren et al. (2001)
2.3	*Tsuga heterophylla*	Seedlings		2.0					350			USA, OR	Running (1976) in Körner et al. (1979)
Deciduous trees													
3.3	*Acacia harpophylla*								286			AU	Tunstall and Connor (1975) in Körner et al. (1979)
4.8	*Acer glabrum*											USA, ID	Cline and Campbell (1976) in Körner et al. (1979)
1.3	*Acer platanoides*											GRH	Holmgren et al. (1965)
2.5	*Acer platanoides*			6.0					580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.1	*Acer rubrum*		13									USA, CT	Turner and Heichel (1977) in Körner et al. (1979)
4.4	*Acer rubrum*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
1.4	*Acer saccharinum*		1									GRH	Pereira and Kozlowski (1977)
2.0	*Acer saccharum*		m	3.0								USA, NH	Federer and Gee (1976)
1.7	*Acer saccharum*	Sapling										USA, MO	Phelps et al. (1976) in Körner et al. (1979)
2.5	*Acer saccharum*	Seedling	1									GRH	Wuenscher and Kozlowski (1971) in Körner et al. (1979)
2.7	*Acer saccharum*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
2.0	*Alnus sinuata*											USA, ID	Cline and Campbell (1976) in Körner et al. (1979)
4.6	*Alnus viridis*								1800			AT	Körner et al. (1979)
3.6	*Amygdalus communis*			3.0					400			IT	Körner et al. (1979)
3.3	*Betula alleghaniensis*		m									USA, NH	Federer and Gee (1976)
1.7	*Betula lutea*	Seedling		0.3								GRH	Loveys et al. (1974) in Körner et al. (1979)
8.1	*Betula verrucosa*											GRH	Holmgren et al. (1965)
4.2	*Betula verrucosa*	Seedling										GRH	Holmgren et al. (1965) in Körner et al. (1979)
1.6	*Castanea sativa*			18.0					400			IT	Körner et al. (1979)
3.0	*Cornus florida*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
5.0	*Eucalyptus camaldulensis*	Seedlings	3 mth									GRH	Pereira and Kozlowski (1976)b in Körner et al. (1979)

2.5	*Eucalyptus globulus*	Seedlings	3 mth							GRH	Pereira and Kozlowski (1976b) in Körner et al. (1979)
2.5	*Eucalyptus pauciflora*			4.0			1645			AU	Slatyer and Morrow (1977) in Körner et al. (1979)
4.2	*Eucalyptus pauciflora*			10.0			915			AU	Slatyer and Morrow (1977) in Körner et al. (1979)
7.5	*Eucalyptus pauciflora*		m	1.5		1800	2040	37S	149E	AU	Körner and Cochrane (1985)
8.5	*Eucalyptus pauciflora*	Sclerophyll		11.5			1215	37S	149E	AU	Körner and Cochrane (1985)
1.7	*Fagus grandifolia*		m							USA, NH	Federer and Gee (1976)
2.0	*Fagus sylvatica*		120							DE	Schulze (1970) in Körner et al. (1979)
2.8	*Fagus sylvatica*			18.0			580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.6	*Fraxinus americana*	Seedlings	1							GRH	Pereira and Kozlowski (1977)
1.8	*Fraxinus americana*	Seedlings	2							USA, WI	Davies and Kozlowski (1975) in Körner et al. (1979)
3.8	*Fraxinus excelsior*			15.0			580			AT	Scheel (unpubl.) in Körner et al. (1979)
2.5	*Fraxinus ornus*			4.0			450			IT	Körner et al. (1979)
2.3	*Juglans nigra*		6 w							GRH	Pereira and Kozlowski (1977)
2.9	*Juglans regia*			16.0			580			AT	Körner et al. (1979)
3.1	*Juglans regia*			12.0			400			IT	Körner et al. (1979)
1.2	*Juglans nigra*	Sapling		5.0						USA, MO	Dougherty et al. (1976) in Körner et al. (1979)
7.1	*Laburnum anagyroides*						580			AT	Scheel (unpubl.) in Körner et al. (1979)
11.7	*Liquidambar styraciflua*	Arboretum			14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
1.1	*Liriodendron tulipifera*		2–3 mth							USA, TN	Richardson et al. (1972) in Körner et al. (1979)
9.3	*Liriodendron tulipifera*	Arboretum			14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
3.3	*Malus domestica*		2–3 mth							GRH	West and Gaff (1976) in Körner et al. (1979)
3.4	*Malus domestica*		9							UK	Landsberg et al. (1975) in Körner et al. (1979)
4.5	*Malus domestica*		9							UK	Landsberg et al. (1976) in Körner et al. (1979)
5.0	*Malus domestica*		6				580			AT	Scheel (unpubl.) in Körner et al. (1979)

Table 4 (*Continued*)

g_s	Sci. name	Furth. Inf.	Age	PlaH	BasA	StoD	MAT	MAP	Hei.	Lat	Lon	Country	Source
6.6	*Malus domestica*		6						580			AT	Scheel (unpubl.) in Körner et al. (1979)
7.1	*Malus domestica*								400			IT	Körner et al. (1979)
9.3	*Nyssa sylvatica*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
2.4	*Olea europea*	Potted trees	6									GRH	Körner et al. (1979)
2.9	*Ostrya carpinifolia*			6.0					450			IT	Körner et al. (1979)
4.3	*Oxydendrum arboreum*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
4.2	*Persica vulgaris*			5.0					400			IT	Körner et al. (1979)
2.5	*Populus grandidentata*											USA, MI	Miller and Gates (1967) in Körner et al. (1979)
4.3	*Populus tremula*											GRH	Holmgren et al. (1965)
4.3	*Populus tremula*											GRH	Holmgren et al. (1965) in Körner et al. (1979)
9.8	*Populus tremuloides*		75	18.0		2000				56N	99W	CA	Dang et al. (1997)
4.0	*Populus tremuluides*											USA, MI	Miller and Gates (1967) in Körner et al. (1979)
3.6	*Prunus armeniaca*		10						640			AT	Körner et al. (1979)
6.3	*Prunus armeniaca*		5						640			AT	Körner et al. (1979)
3.3	*Prunus avium*			6.0					400			IT	Körner et al. (1979)
4.5	*Prunus avium*			10.0					580			AT	Scheel (unpubl.) in Körner et al. (1979)
4.5	*Pyrus communis*			4.0					400			IT	Körner et al. (1979)
7.2	*Quercus muehlenbegil*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
2.0	*Quercus alba*			19.0								USA, MO	Hinckley et al. (1975) in Körner et al. (1979)
2.2	*Quercus alba*	Saplings		3.0								USA, MO	Phelps et al. (1976) in Körner et al. (1979)
9.5	*Quercus alba*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
0.8	*Quercus macrocarpa*	Seedlings	3–4 mth									GRH	Wuenscher and Kozlowski (1971) in Körner et al. (1979)
9.5	*Quercus prinus*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
2.8	*Quercus pubescens*			3.0					450			IT	Körner et al. (1979)
0.9	*Quercus robur*											GRH	Holmgren et al. (1965)
2.9	*Quercus robur*			20.0					580			AT	Scheel (unpubl.) in Körner et al. (1979)
2.0	*Quercus rubra*		9									USA, CT	Turner and Heichel (1977) in Körner et al. (1979)
1.8	*Quercus rubra*	Saplings		3.0								USA, MO	Phelps et al. (1976) in Körner et al. (1979)

6.8	*Quercus rubra*	Arboretum					14.0	1385		36N	84W	USA, TN	Augé et al. (2000)
1.2	*Quercus rubra*	Seedlings	30 d									GRH	Tebbest et al. (1976) in Körner et al. (1979)
2.5	*Quercus rubra*	Seedlings	3–4 mth									GRH	Wuenscher and Kozlowski (1971) in Körner et al. (1979)
2.0	*Quercus velutina*		3–4 mth									GRH	Wuenscher and Kozlowski (1971) in Körner et al. (1979)
1.6	*Quercus velutina*	Saplings		3.0								USA, MO	Phelps et al. (1976) in Körner et al. (1979)
2.4	*Rhus laurina*											USA, CA	Poole and Miller (1975) in Körner et al. (1979)
4.2	*Rhus laurina*											USA, CA	Poole and Miller (1975) in Körner et al. (1979)
3.1	*Tilia cordata*			20.0					580			AT	Scheel (unpubl.) in Körner et al. (1979)
1.8	*Ulmus americana*	Seedlings	1									GRH	Pereira and Kozlowski (1977)

g_s (mm s^{-1})—maximum of stomatal conductance. Sci. name: scientific names for species were taken as published by authors and not transformed into current nomenclature; Furth. Inf.: further information given in literature; Age: d: days, w: weeks, mth: months, m: mature; PlaH: plant height (m); BasA: basal area (m^2 ha^{-1}); StoD: stock density (ha^{-1}); MAT: mean annual temperature (°C); MAP: mean annual precipitation (mm); Hei: height above sea level (m); Lat: latitude (°); Lon: longitude (°); n.d.: no details given; Country: GRH: greenhouse, abbreviation of countries follows ISO 3166.

Table 5
Maximum plant height—H_{max}

H_{max}	Sci. name	Country	Source
Crops			
0.60	*Avena sativa*	n.d.	Conert (2000)
0.60	*Avena sativa*	n.d.	Rothmaler (1990)
1.00	*Avena sativa*	n.d.	Conert (2000)
1.50	*Avena sativa*	n.d.	Rothmaler (1990)
0.50	*Beta vulgaris*	n.d.	Rothmaler (1990)
1.50	*Beta vulgaris*	n.d.	Rothmaler (1990)
1.00	*Beta vulgaris*	n.d.	Polunin (1971)
1.00	*Beta vulgaris*	n.d.	Polunin (1971)
1.00	*Brassica napus*	n.d.	Rothmaler (1990)
1.40	*Brassica napus*	n.d.	Rothmaler (1990)
0.40	*Brassica rapa*	n.d.	Rothmaler (1990)
0.80	*Brassica rapa*	n.d.	Rothmaler (1990)
0.40	*Glycine max*	n.d.	Polunin (1971)
1.00	*Glycine max*	n.d.	Polunin (1971)
0.50	*Helianthus annuus*	n.d.	Fick (1989)
1.00	*Helianthus annuus*	n.d.	Rothmaler (1990)
2.00	*Helianthus annuus*	n.d.	Rothmaler (1990)
4.00	*Helianthus annuus*	n.d.	Fick (1989)
0.60	*Hordeum vulgare*	n.d.	Rothmaler (1990)
1.20	*Hordeum vulgare*	n.d.	Rothmaler (1990)
0.40	*Lycopersicum esculentum*	n.d.	Rothmaler (1990)
1.00	*Lycopersicum esculentum*	n.d.	Polunin (1971)
1.50	*Lycopersicum esculentum*	n.d.	Rothmaler (1990)
0.75	*Nicotiana tabacum*	n.d.	Rothmaler (1990)
3.00	*Nicotiana tabacum*	n.d.	Rothmaler (1990)
2.00	*Phaseolus coccineus*	n.d.	Polunin (1971)
3.50	*Phaseolus coccineus*	n.d.	Rothmaler (1990)
5.00	*Phaseolus coccineus*	n.d.	Polunin (1971)
0.30	*Phaseolus vulgaris*	n.d.	Polunin (1971)
3.00	*Phaseolus vulgaris*	n.d.	Polunin (1971)
4.00	*Phaseolus vulgaris*	n.d.	Rothmaler (1990)
0.70	*Secale cereale*	n.d.	Rothmaler (1990)
2.00	*Secale cereale*	n.d.	Rothmaler (1990)
0.40	*Solanum tuberosum*	n.d.	Rothmaler (1990)
1.00	*Solanum tuberosum*	n.d.	Rothmaler (1990)
0.70	*Triticum aestivum*	n.d.	Rothmaler (1990)
1.60	*Triticum aestivum*	n.d.	Rothmaler (1990)
0.60	*Triticum spelta*	n.d.	Rothmaler (1990)
1.50	*Triticum spelta*	n.d.	Rothmaler (1990)
1.00	*Zea mays*	n.d.	Rothmaler (1990)
3.00	*Zea mays*	n.d.	Rothmaler (1990)
Herbs, forbs, grasses			
1.00	*Alopecurus pratensis*	n.d.	Aichele and Schwegler (1991)
0.50	*Arrhenatheretum*	n.d.	Aichele and Schwegler (1991)
0.56	*Arrhenatheretum*	DE	Ellenberg (1996)
1.50	*Arrhenatheretum*	n.d.	Aichele and Schwegler (1991)
1.20	*Arrhenatherum, Agropyro-Rumicion*	DE	Geyger (1964)
1.50	*Arrhenatherum, Agropyro-Rumicion*	DE	Geyger (1964)
1.70	*Arrhenatherum, Agropyro-Rumicion*	DE	Geyger (1964)
1.50	*Arrhenatherum, Cirsio-Polygonum*	DE	Geyger (1964)
1.60	*Calamgrostis canescens*	DE	Geyger (1964)
1.60	*Calamgrostis canescens*	DE	Geyger (1964)

Table 5 (*Continued*)

H_{max}	Sci. name	Country	Source
0.30	*Caltha palustris*	n.d.	Aichele and Schwegler (1991)
0.90	*Carex aquatilis*	n.d.	Aichele and Schwegler (1991)
2.00	*Carex gracilis*	DE	Geyger (1964)
0.80	*Cirsio-Polygonum*	DE	Geyger (1964)
1.20	*Cirsio-Polygonum*	DE	Geyger (1964)
1.20	*Cirsio-Polygonum*	DE	Geyger (1964)
1.40	*Cirsio-Polygonum*	DE	Geyger (1964)
1.60	*Cirsio-Polygonum*	DE	Geyger (1964)
1.60	*Cirsio-Polygonum*	DE	Geyger (1964)
1.75	*Cirsio-Polygonum*	DE	Geyger (1964)
1.80	*Cirsio-Polygonum*	DE	Geyger (1964)
0.80	*Cirsium oleracum-Polygonum bistorta*	DE	Ellenberg (1996)
1.00	*Dactylis glomerata*	n.d.	Aichele and Schwegler (1991)
1.50	*Deschampsia cespitosa*	n.d.	Aichele and Schwegler (1991)
1.00	*Equisetum arvense*	n.d.	Ellenberg (1996)
1.00	*Festuca rubra*	n.d.	Aichele and Schwegler (1991)
1.50	*Festuca rubra*	n.d.	Aichele and Schwegler (1991)
1.20	*Glyceria maxima*	DE	Geyger (1964)
2.50	*Glyceria maxima*	n.d.	Aichele and Schwegler (1991)
1.00	*Holcus lanatus*	n.d.	Aichele and Schwegler (1991)
0.60	*Impatiens parviflora*	n.d.	Aichele and Schwegler (1991)
0.60	*Lolium perenne*	n.d.	Aichele and Schwegler (1991)
1.60	*Petasites hybrides*	DE	Geyger (1964)
2.00	*Phalaris arundinacea*	n.d.	Aichele and Schwegler (1991)
2.75	*Phragmitis communis*	DE	Geyger (1964)
3.20	*Phragmitis communis*	DE	Geyger (1964)
3.30	*Phragmitis communis*	DE	Geyger (1964)
0.40	*Trifolium pratense*	n.d.	Aichele and Schwegler (1991)
0.58	*Trisetum* spp.	DE	Ellenberg (1996)
0.43	*Trollius europaeus-Polygonum bistorta*	DE	Ellenberg (1996)
1.50	*Veronico-Cirsio-Polygonum*	DE	Geyger (1964)
1.60	*Veronico-Cirsio-Polygonum*	DE	Geyger (1964)
0.60	*Vicia sepium*	n.d.	Aichele and Schwegler (1991)

H_{max} (m)—maximum plant height. Sci. name: scientific names for species were taken as published by authors and not transformed into current nomenclature; Country: n.d.: no details given; abbreviation of countries follows ISO 3166.

Measurement of the rooting depths is a destructive technique in which plant roots have to be excavated. Authors usually present data for the deepest root found (Köstler, 1968), whereas in some cases researchers divided data into root classes and published depth for the specific root class (e.g. Raspe and Haug, 1998).

Most of maximum rooting depth for herbs, forbs, grasses and crops (Table 6) are read off graphs published by Ellenberg (1996) or are taken from Kutschera (1960), whereas data for coniferous and deciduous trees is selected from several sources (Köstler et al., 1968; Schmidt-Vogt, 1987; Gregory, 1988; Rastin and Mintenig, 1992; Raspe and Haug, 1998). General plant handbooks also provide maximum root length of certain species, though the influence of soil conditions is usually not described in detail.

Even though the focus in the collection of maximum root depths is on species from mid-European ecosystems, maximum root depths of temperate vegetation types in other temperate regions will not differ much as they mainly depend on physical soil properties (Kutschera, 1960; Köstler, 1968; Sitte et al., 1999). Maximum root depth of crops and pasture species are lower on average (1.4 ± 0.6 and 0.9 ± 0.6 m, respectively) and show a smaller standard deviation than those of deciduous and coniferous trees (1.9 ± 1.8 and 2.1 ± 1.3 respectively) (Table 7). Extensive root systems for deciduous trees in deep soils are found in depths of 4.0 m and more, whereas rootlets in clefts of

Table 6
Root depth—RD_{max}

RD_{max}	Sci. name	Furth. Inf.	Age	Country	Source
Crops					
0.61	*Avena sativa*	Short-grass prarie		USA, NE	Weaver (1926) in Kutschera (1960)
0.84	*Avena sativa*			AT	Kutschera (1960)
0.85	*Avena sativa*	Sandy loam		n.d.	Kutschera (1960)
1.05	*Avena sativa*			n.d.	Könnecke (1967)
1.15	*Avena sativa*			DE	Thiel (1865) in Kutschera (1960)
1.60	*Avena sativa*	Black earth over loess		n.d.	Günther (1951) in Kutschera (1960)
2.47	*Avena sativa*			n.d.	Schulze (1911) in Kutschera (1960)
0.90	*Beta vulgaris*			UK	Durrant et al. (1973) in Gregory (1988)
1.10	*Beta vulgaris*			n.d.	Könnecke (1967)
0.85	*Brassica napus*			AT	Kutschera (1960)
1.02	*Brassica napus*			n.d.	Könnecke (1967)
1.30	*Brassica napus*			DE	Schubert (1885) in Kutschera (1960)
1.30	*Brassica napus*			DE	Könnecke (1951) in Kutschera (1960)
1.50	*Brassica napus*			DE	Römer-Scheffer (1953) in Kutschera (1960)
1.64	*Brassica napus*			AT	Kutschera (1960)
1.66	*Brassica napus*			DE	Pistohlkors (1898) in Kutschera (1960)
1.75	*Brassica napus*			DE	Pistohlkors (1898) in Kutschera (1960)
1.00	*Cannabis sativa*			n.d.	Pistohlkors (1898) in Kutschera (1960)
1.12	*Cannabis sativa*			n.d.	Kutschera (1960)
1.80	*Glycine max*			USA	Sivakumar et al. (1977) in Gregory (1988)
1.60	*Helianthus annuus*			AT	Kutschera (1960)
1.80	*Helianthus annuus*			DE	Könekamp (1942) in Kutschera (1960)
2.75	*Helianthus annuus*			USA, NE	Weaver (1926) in Kutschera (1960)
0.76	*Hordeum distichum*	Short-grass prarie		USA, NE	Weaver (1926) in Kutschera (1960)
0.94	*Hordeum distichum*	Gley with mull		AT	Kutschera (1960)
1.20	*Hordeum distichum*	Black earth		DE	Walter (1951) in Kutschera (1960)
1.50	*Hordeum distichum*	Black earth		DE	Walter (1951) in Kutschera (1960)
1.75	*Hordeum distichum*	Brown soil		AT	Kutschera (1960)
1.98	*Hordeum distichum*	Tall-grass prarie		USA, NE	Weaver (1926) in Kutschera (1960)
2.59	*Hordeum distichum*			n.d.	Schulze (1911) in Kutschera (1960)
0.98	*Hordeum vulgare*			n.d.	Könnecke (1967)
1.01	*Hordeum vulgare*			n.d.	Könnecke (1967)
1.36	*Medicago sativa*	Loam		AT	Kutschera (1960)
1.75	*Medicago sativa*	Sand		n.d.	Pistohlkors (1898) in Kutschera (1960)
1.85	*Medicago sativa*	Black earth over loess		DE	Könnecke (1951) in Kutschera (1960)
2.20	*Medicago sativa*	Stony sandy loam		AT	Kutschera (1960)
3.65	*Medicago sativa*			USA, NE	Weaver (1926) in Kutschera (1960)
3.80	*Medicago sativa*	Stony sandy loam		AT	Kutschera (1960)
1.45	*Medicago* spp.			n.d.	Könnecke (1967)
0.67	*Pisum sativum*			n.d.	Könnecke (1967)
1.50	*Pisum sativum*			AU	Hamblin and Hamblin (1985) in Gregory (1988)
0.75	*Secale sereale*			n.d.	Kraus (1914) in Kutschera (1960)
0.90	*Secale sereale*	Black earth, middle-deep		n.d.	Günther (1951) in Kutschera (1960)
0.90	*Secale sereale*	Fraible soil over hardpan		n.d.	Günther (1951) in Kutschera (1960)
1.00	*Secale sereale*	Humic sandy loam		n.d.	Günther (1951) in Kutschera (1960)
1.05	*Secale sereale*			n.d.	Könnecke (1967)

Table 6 (*Continued*)

RD_{max}	Sci. name	Furth. Inf.	Age	Country	Source
1.20	*Secale sereale*	Brown soil with shingle		AT	Kutschera (1960)
1.23	*Secale sereale*			n.d.	Pistohlkors (1898) in Kutschera (1960)
1.25	*Secale sereale*			DE	Schubart (1855) in Kutschera (1960)
1.50	*Secale sereale*			n.d.	Pistohlkors (1898) in Kutschera (1960)
1.52	*Secale sereale*	Dry sandy soil		USA, CO	Weaver (1926) in Kutschera (1960)
1.80	*Secale sereale*	Black earth, deep			Günther (1951) in Kutschera (1960)
2.30	*Secale sereale*	Wet sandy soil		USA, NE	Weaver (1926) in Kutschera (1960)
0.80	*Solanum tuberosum*			UK	Durrant et al. (1973) in Gregory (1988)
0.93	*Solanum tuberosum*			n.d.	Könnecke (1967)
1.13	*Solanum tuberosum*			AT	Kutschera (1960)
1.20	*Solanum tuberosum*			n.d.	Heyl (1942) in Kutschera (1960)
1.43	*Solanum tuberosum*			USA, NE	Weaver (1926) in Kutschera (1960)
2.20	*Solanum tuberosum*	Marly-humic loam		n.d.	Böhme (1925) in Kutschera (1960)
0.79	*Sorghum* spp.			n.d.	Könnecke (1967)
1.35	*Sorghum* spp.			AU	Myers (1980) in Gregory (1988)
0.50	*Triticum aestivum*			n.d.	Kraus (1914) in Kutschera (1960)
0.75	*Triticum aestivum*			n.d.	Kraus (1914) in Kutschera (1960)
0.96	*Triticum aestivum*			n.d.	Könnecke (1967)
1.00	*Triticum aestivum*			UK	Ellis et al. (1984) in Gregory (1988)
1.05	*Triticum aestivum*	Mesotrophic brown soil over granite		AT	Kutschera (1960)
1.09	*Triticum aestivum*			n.d.	Pistohlkors (1898) in Kutschera (1960)
1.20	*Triticum aestivum*	Gley with deep mull horizon		AT	Kutschera (1960)
1.30	*Triticum aestivum*	Mesotrophic brown soil over shingle		AT	Kutschera (1960)
1.40	*Triticum aestivum*	Calcic brown soil over loess		AT	Kutschera (1960)
1.40	*Triticum aestivum*			AU	Hamblin and Hamblin (1985) in Gregory (1988)
1.40	*Triticum aestivum*	Black earth		n.d.	Könnecke (1951) in Kutschera (1960)
1.60	*Triticum aestivum*			CA	Pavlychenko (1937) in Kutschera (1960)
1.79	*Triticum aestivum*	Gley with deep mull horizon		AT	Kutschera (1960)
1.88	*Triticum aestivum*	Compact soil		DE	Schubart (1855) in Kutschera (1960)
2.00	*Triticum aestivum*			UK	Gregory et al. (1978) in Gregory (1988)
2.20	*Triticum aestivum*	Friable soil		DE	Schubart (1855) in Kutschera (1960)
2.22	*Triticum aestivum*	Silty loam		USA, NE	Weaver (1926) in Kutschera (1960)
2.77	*Triticum aestivum*			n.d.	Schulze (1911) in Kutschera (1960)
0.90	*Zea mays*			n.d.	Könnecke (1967)
1.20	*Zea mays*	Gleyey brown soil		AT	Kutschera (1960)
2.41	*Zea mays*			USA, NE	Weaver (1926) in Kutschera (1960)
Herbs, forbs, grasses					
0.42	*Arabidopsis thaliana*			AT	Kutschera (1960)
0.75	*Arrhenatheretum* spp.			DE	Ellenberg (1996)
0.75	*Arrhenatherum elatius*			n.d.	Ellenberg (1996)
1.95	*Avena sativa*	Tall-grass prarie		USA, NE	Weaver (1926) in Kutschera (1960)
0.70	*Cirsium oleracum-Polygonum bistorta*			DE	Ellenberg (1996)
0.80	*Equisetum arvense*			n.d.	Ellenberg (1996)
0.80	*Festuca rubra*			n.d.	Ellenberg (1996)
0.70	*Knautia arvensis*			n.d.	Ellenberg (1996)

Table 6 (*Continued*)

RD_{max}	Sci. name	Furth. Inf.	Age	Country	Source
1.35	*Lolium multiflorum*			AT	Kutschera (1960)
1.45	*Lolium multiflorum*			CH	Kauter (1933) in Kutschera (1960)
1.80	*Phragmitis communis*			AT	Kutschera (1960)
0.14	*Plantago lanceolata*			UK	Anderson (1927) in Kutschera (1960)
0.59	*Plantago lanceolata*			AT	Kutschera (1960)
0.60	*Plantago lanceolata*			DE	Wehsarg (1935) in Kutschera (1960)
0.85	*Plantago lanceolata*			n.d.	Ellenberg (1996)
0.70	*Poa pratensis*	Valley bog		DE	Kamprath (1933) in Kutschera (1960)
0.72	*Poa pratensis*	Loamy brown soil over shingle		AT	Kutschera (1960)
0.83	*Poa pratensis*	Clay		DE	Kamprath (1933) in Kutschera (1960)
0.89	*Poa pratensis*	Loam		DE	Kamprath (1933) in Kutschera (1960)
0.94	*Poa pratensis*	Sand		DE	Kamprath (1933) in Kutschera (1960)
1.22	*Poa pratensis*			USA, KS	Kutschera (1960)
1.44	*Poa pratensis*	Stony sandy brown soil		AT	Kutschera (1960)
1.52	*Poa pratensis*	Silty loam		USA, NE	Weaver (1926) in Kutschera (1960)
1.83	*Poa pratensis*	Clay loam		USA, NE	Weaver (1926) in Kutschera (1960)
2.13	*Poa pratensis*	Sandy soil		USA, NE	Weaver (1926) in Kutschera (1960)
0.25	*Polygonum aviculare*			DE	Meisel (1955) in Kutschera (1960)
0.72	*Polygonum aviculare*			AT	Kutschera (1960)
0.80	*Trifolium pratense*			n.d.	Ellenberg (1996)
0.81	*Trifolium pratense*	Sandy brown soil		AT	Kutschera (1960)
1.32	*Trifolium pratense*			n.d.	Könnecke (1967)
1.35	*Trifolium pratense*	Black earth over loess		DE	Könnicke (1951) in Kutschera (1960)
3.04	*Trifolium pratense*			USA, NE	Weaver (1926) in Kutschera (1960)
0.15	*Trifolium repens*			n.d.	Fraas in Kutschera (1960)
0.18	*Trifolium repens*			n.d.	Pistohlkors (1898) in Kutschera (1960)
0.40	*Trifolium repens*	Loamy sand		DE	Kraus (1914) in Kutschera (1960)
0.61	*Trifolium repens*			USA, NY	Beckwith (1886) in Kutschera (1960)
0.70	*Trifolium repens*	Stoney sandy loam		AT	Kutschera (1960)
0.76	*Trifolium repens*	Silty loam		USA, NE	Weaver (1926) in Kutschera (1960)
1.00	*Trifolium* spp.			AU	Hamblin and Hamblin (1985) in Gregory (1988)
0.68	*Trisetum* spp.			DE	Ellenberg (1996)
0.70	*Trollius europaeus-Polygonum bistorta*			DE	Ellenberg (1996)
0.80	*Vicia sativa*			AT	Kutschera (1960)
Coniferous trees					
0.40	*Abies alba*		10	n.d.	Köstler et al. (1968)
1.50	*Abies alba*	Heavy clay	100	DE	Köstler et al. (1968)
1.60	*Abies alba*		40	n.d.	Köstler et al. (1968)
1.30	*Larix decidua*	Pseudogley		DE	Köstler et al. (1968)
2.50	*Larix decidua*	Deep loamy sand		n.d.	Köstler et al. (1968)
0.80	*Larix leptolepis*	Clay, alternate moist	60	DE	Schoch (1964) in Köstler et al. (1968)
1.20	*Larix leptolepis*		60	DE	Schoch (1964) in Köstler et al. (1968)
1.20	*Larix leptolepis*	Pseudogley	60	DE	Köstler et al. (1968)
1.70	*Larix leptolepis*	Pseudogley	60	DE	Köstler et al. (1968)
2.80	*Larix leptolepis*	Sand over loam		DE	Yao-Ming (1962) in Köstler et al. (1968)
1.00	*Picea abies*			DE	Köstler (1956) in Schmidt-Vogt (1987)
1.10	*Picea abies*		80	DE	Rastin and Mintenig (1992)
1.50	*Picea abies*			DE	Graser (1935) in Köstler et al. (1968)
1.70	*Picea abies*			DE	Schoch (1964) in Köstler et al. (1968)

Table 6 (*Continued*)

RD_{max}	Sci. name	Furth. Inf.	Age	Country	Source
2.00	*Picea abies*			DE	Raspe et al. (1998)
2.00	*Picea abies*			n.d.	Büsgen-Münch (1927) in Köstler et al. (1968)
2.00	*Picea abies*		30	n.d.	Köstler et al. (1968)
2.10	*Picea abies*			DE	Vater (1927) in Köstler et al. (1968)
2.35	*Picea abies*			DE	Wagenknecht and Belitz (1959) in Schmidt-Vogt (1987)
3.25	*Picea abies*			n.d.	von Kruedener (1943) in Schmidt-Vogt (1987)
4.40	*Picea abies*			n.d.	Römper (1954) in Schmidt-Vogt (1987)
4.50	*Picea abies*			n.d.	Wagenknecht (1955) in Köstler et al. (1968)
6.00	*Picea abies*			n.d.	Jüttner (1954) in Schmidt-Vogt (1987)
2.52	*Pinus* spp.	Mixed stand with *Betula verrucosa*		RU	Rachtejenko (1952) in Köstler et al. (1968)
1.40	*Pinus sylvestris*	Rendzina on shingle		DE	Köstler et al. (1968)
1.50	*Pinus sylvestris*		20	DE	Engler (1903) in Köstler et al. (1968)
1.50	*Pinus sylvestris*		55	UK	Ovington (1957)
1.80	*Pinus sylvestris*			n.d.	Rutter (1968)
2.50	*Pinus sylvestris*		40	n.d.	Köstler et al. (1968)
6.00	*Pinus sylvestris*			n.d.	Wiedemann (1927) in Köstler et al. (1968)
0.70	*Pseudotsuga taxifolia*	Fine-textured loam		n.d.	Dertinger (1964) in Köstler et al. (1968)
0.80	*Pseudotsuga taxifolia*	Pleistocene sand	30	n.d.	Köstler et al. (1968)
1.00	*Pseudotsuga taxifolia*	Mesic dense loam over shingle rich loam	62	DE	Köstler et al. (1968)
1.80	*Pseudotsuga taxifolia*	Dense weathered old moraine		DE	Köstler et al. (1968)
2.00	*Pseudotsuga taxifolia*	Loam derived from loess	50	n.d.	Köstler et al. (1968)
2.20	*Pseudotsuga taxifolia*		40	n.d.	Köstler et al. (1968)
3.20	*Pseudotsuga taxifolia*		70	n.d.	Köstler et al. (1968)
Deciduous trees					
0.50	*Acer pseudoplatanus*		2	DE	Pfeil (1860) in Köstler et al. (1968)
0.70	*Acer pseudoplatanus*	Shingle		n.d.	Köstler et al. (1968)
1.36	*Acer pseudoplatanus*		5	n.d.	Hoffmann (1959) in Köstler et al. (1968)
1.40	*Acer pseudoplatanus*	Bronw earth	70	DE	Schoch (1964) in Köstler et al. (1968)
0.50	*Alnus glutinosa*		2	CH	Engler (1903) in Kreutzer (1961) in Köstler et al. (1968)
1.50	*Alnus glutinosa*		10	CH	Engler (1903); Kreutzer (1961) in Köstler et al. (1968)
1.60	*Alnus glutinosa*	Dense soil	30	n.d.	Köstler et al. (1968)
1.75	*Alnus glutinosa*		25	DE	Schoch (1964) in Köstler et al. (1968)
1.80	*Alnus glutinosa*	Dense sandy loam	45	DE	Köstler et al. (1968)
2.10	*Alnus glutinosa*	Loam over sand, high groundwater level		SI	Bibelriether (1964) in Köstler et al. (1968)
3.80	*Alnus glutinosa*		75	DE	Schoch (1964) in Köstler et al. (1968)
0.50	*Betula verrucosa*	Acidified loam	50	DE	Schoch (1964) in Köstler et al. (1968)
0.70	*Betula verrucosa*	Pseudogley-Podsol	9	CZ	Zakopal (1958) in Köstler et al. (1968)
1.10	*Betula verrucosa*	Sandy gravelly loam	60	DE	Schoch (1964) in Köstler et al. (1968)
1.10	*Betula verrucosa*		12		Köstler et al. (1968)
1.20	*Betula verrucosa*	Heavy loam	70	DE	Köstler et al. (1968)
1.20	*Betula verrucosa*	Sandy-loamy weathered gneiss	60	DE	Köstler et al. (1968)

Table 6 (*Continued*)

RD_{max}	Sci. name	Furth. Inf.	Age	Country	Source
1.30	*Betula verrucosa*	Clay	45	DE	Köstler et al. (1968)
1.30	*Betula verrucosa*	Pseudogley	90	DE	Köstler et al. (1968)
1.50	*Betula verrucosa*	Pseudogley-Podsol	15	CZ	Zakopal (1958) in Köstler et al. (1968)
1.50	*Betula verrucosa*	Loam	50		Köstler et al. (1968)
2.60	*Betula verrucosa*	Poor sand	17		Köstler et al. (1968)
3.04	*Betula verrucosa*			RU	Rachtejenko (1952) in Köstler et al. (1968)
3.80	*Betula verrucosa*	Mixed stand with Pinus spp.		RU	Rachtejenko (1952) in Köstler et al. (1968)
4.02	*Betula verrucosa*	Mixed stand		RU	Rachtejenko (1952) in Köstler et al. (1968)
1.40	*Carpinus betulus*	Acidified clay	70	DE	Schoch (1964) in Köstler et al. (1968)
1.50	*Carpinus betulus*		65	n.d.	Köstler et al. (1968)
0.60	*Fagus sylvatica*	Clay, alternate moist		DE	Schoch (1964) in Köstler et al. (1968)
0.80	*Fagus sylvatica*	On Tertiary shingle		n.d.	Köstler et al. (1968)
0.90	*Fagus sylvatica*	Heavy clay		DE	Köstler et al. (1968)
1.80	*Fagus sylvatica*	Deep loam		DE	Graser (1928) in Köstler et al. (1968)
3.00	*Fagus sylvatica*	Deep sand		DE	Ganssen (1934) in Köstler et al. (1968)
3.40	*Fagus sylvatica*	Loamy clefts in sandstone quarry		n.d.	Hilf (1927) in Köstler et al. (1968)
12.00	*Fagus sylvatica*	Stony-gritty soil derived from granite and gneiss		n.d.	Köstler et al. (1968)
1.10	*Fraxinus excelsior*	Loam over clay	40	DE	Köstler et al. (1968)
1.40	*Fraxinus excelsior*	Coarse textured loam on weathered limestone	90	n.d.	Köstler et al. (1968)
1.50	*Fraxinus excelsior*		30	n.d.	Köstler et al. (1968)
2.50	*Populus canadensis*	Sand	10	n.d.	Köstler et al. (1968)
1.80	*Populus tremoluides*			n.d.	Brown and Tompson (1965) in Rutter (1968)
1.20	*Populus tremula*	Clay, alternate moist	40	DE	Schoch (1964) in Köstler et al. (1968)
1.40	*Populus tremula*	Pseudogleyig loam	50	DE	Köstler et al. (1968)
1.50	*Populus tremula*	Clay	60	DE	Köstler et al. (1968)
1.00	*Quercus petrea*	Loamy sand over various substrates		DE	Köstler et al. (1968)
1.30	*Quercus robur*	Shallow soil on weathered shingle	100	n.d.	Köstler et al. (1968)
1.40	*Quercus robur*	Clay, alternate moist	100	DE	Schoch (1964) in Köstler et al. (1968)
1.60	*Quercus robur*	Pseudovergleyt lehm	100	DE	Schoch (1964) in Köstler et al. (1968)
9.00	*Quercus robur*	Steppe soil	13	RU	Walter (1962) in Köstler et al. (1968)
0.90	*Quercus rubra*	Pseudogley derived from loess-loam	45	DE	Köstler et al. (1968)
0.95	*Quercus rubra*	Clay, alternate moist	25	DE	Schoch (1964) in Köstler et al. (1968)
1.30	*Quercus rubra*	Fine-textured loam	50	DE	Köstler et al. (1968)
3.60	*Quercus rubra*	Sand over loam	65	n.d.	Lemke (1956) in Köstler et al. (1968)
2.00	*Robinia pseudoacacia*		2	DE	Hoffmann (1966) in Köstler et al. (1968)
2.60	*Robinia pseudoacacia*	Sand	28	HU	Ijjasz (1939) in Köstler et al. (1968)
3.00	*Robinia pseudoacacia*	Sand		n.d.	Scamoni (1952) in Köstler et al. (1968)
3.25	*Robinia pseudoacacia*	Deep sand	2	DE	Wächter (1921) in Köstler et al. (1968)
0.80	*Tilia cordata*	Pseudogley	50	n.d.	Köstler et al. (1968)
0.90	*Tilia cordata*	Coarse textured soil	90	DE	Köstler et al. (1968)
1.30	*Tilia cordata*	Loess-loam	65	DE	Köstler et al. (1968)
1.30	*Tilia cordata*	Sandy loam	30	n.d.	Köstler et al. (1968)

Table 6 (*Continued*)

RD_{max}	Sci. name	Furth. Inf.	Age	Country	Source
0.50	*Ulmus montana*	Heavy clay	43	DE	Köstler et al. (1968)
0.80	*Ulmus montana*	Alluvial gravel and sand	88	DE	Köstler et al. (1968)
1.20	*Ulmus montana*	Heavy pseudogley	75	DE	Köstler et al. (1968)
1.60	*Ulmus montana*	Heavy pseudogley	50	DE	Köstler et al. (1968)

RD_{max} (m)—maximum depth in which single roots were found. Sci. name: scientific names for species were taken as published by authors and not transformed into current nomenclature; Furth. Inf.: further information given in literature; Country: n.d.: no details given; abbreviation of countries follows ISO 3166.

solid rock layers have been found to grow as deep as 12.0 m (Table 6). Mean RD_{max} for coniferous trees as compared to deciduous trees is approximately 0.2 m higher, even though the span of maximum root depth for coniferous trees is comparatively narrower and maximum values are lower as well.

3. Global assessment of parameter ranges

A synopsis of the literature review undertaken for six parameters important in ecological and hydrological modelling is given in Table 7 with overall mean, standard deviation, median, minimum, maximum and total number of species investigated for the main land cover crops, herbs/forbs/grasses, coniferous and deciduous trees in global temperate ecosystems.

Overall, a total of 1244 single plant parameter values have been collected for the main land cover types of forests, agriculture and pasture. An additional 94 data sets for shrubs, woodlands and understory vegetation are given. The main findings for the analysed plant parameters can be summarised as (Table 7):

- Mean for minimum and maximum albedo of deciduous forest trees, pasture and crops species are in a range of 0.19–0.27 whereas values for coniferous forest trees are substantially lower with a range of 0.11–0.14. Standard deviation is relatively low with an average of 0.05.
- A clear distinction between forest species and low-growing herbaceous plants and crops can be found for g_s with around 2.5–4.0 and 6 mm s^{-1}, respectively. Variation within data sets leads to high standard deviation for all land cover types.
- I_c of deciduous trees is significantly lower as compared to I_c of coniferous trees. Mean I_c of crops is highest (2.6 mm) compared to other land covers. Taking into account the proposed surcharge of 2.0 mm for I_c of understory vegetation in forest stands, total I_c for coniferous forest stands rises to 3.9 mm and to 3.0 mm for deciduous forest stands respectively.
- LAI for the investigated vegetation types cover a wide range and a maximum value of 23.5 was found for a coniferous forest species. Mean LAI of forest trees and herbs/forbs/grasses differ moderately between 5.4 and 6.3.
- Even though plant species develop different root systems soil properties are a key factor in maximum root depth. Trees in general root slightly deeper than crops or pasture species, even though ranges broadly overlap.

Values for certain plant parameters have to be preset in nearly all ecological or hydrological process orientated models. Usually these are taken from a limited number of sources, hoping that the cited values fulfil the assumption of being in fact representative for the given land cover, e.g. the assumption of known distribution of parameters for Monte Carlo simulation (Franks and Beven, 1997; Veihe and Quinton, 2000; Eckhardt et al., 2003). To test whether the calculated means of the data sets in Table 7 meet this criteron, normal distribution is tested by the Kolmogorov–Smirnov-test if $N > 25$, which is true for 22 out of the 26 cases for the main land cover types investigated. Normal distribution is verifiable for 15 plant parameters and land cover types. Outliers in five of the 22 cases superpose normal distribution ((1) LAI crops 10.0, Table 2; (2) LAI coniferous trees 23.5, 16.7, 15.5, Table 2; (3) g_s pasture 33.1, 29.2, 26.3, 25.0 mm s^{-1}, Table 4; (4) g_s deciduous trees 11.7, 9.8, 9.5 mm s^{-1}, Table 4; (5) RD_{max} pasture 3.04 m, Table 6). There are a number of reasons for outliers in plant parameter investigations, attributable

Table 7
Parameter values (median, minimum and maximum) for land covers in global temperate ecosystems

	Main land cover types				Additional information		Total
	Crops	Herbs, forbs, grasses	Coniferous forest	Deciduous forest	Shrubs, woodland	Under story	
Minimum albedo (a)							
Mean	0.20	0.19	0.11	0.21	0.25		
Min	0.10	0.02	0.05	0.09	0.10		
Max	0.28	0.36	0.17	0.32	0.37		
Median	0.20	0.20	0.10	0.23	0.30		
S.D.	0.05	0.07	0.03	0.05	0.10		
N	36*	28*	19	37*	7		127
Maximum albedo (a)							
Mean	0.24	0.27	0.14	0.27	0.29		
Min	0.18	0.05	0.06	0.18	0.10		
Max	0.32	0.42	0.23	0.36	0.44		
Median	0.24	0.27	0.14	0.28	0.37		
S.D.	0.03	0.07	0.05	0.05	0.14		
N	36*	28*	19	37*	7		127
Stomatal conductance, g_s ($mm\,s^{-1}$)							
Mean	6.1	6.2	2.5	3.8	7.3		
Min	1.0	0.8	0.5	0.8	1.0		
Max	23.8	33.1	7.4	11.7	37.5		
Median	5.0	5.2	2.0	3.1	3.3		
S.D.	4.3	6.0	1.6	2.5	9.1		
N	62*	82$^{(*)}$	53*	82$^{(*)}$	20		299
Maximum plant height, H_{max} (m)							
Mean	1.44	1.35	n.d.	n.d.			
Min	0.30	0.30	n.d.	n.d.			
Max	5.00	3.30	n.d.	n.d.			
N	41$^{n.s.}$	43*	n.d.	n.d.			84
Interception capacity, I_c (mm)							
Mean	2.6	1.9	1.9	1.0	1.1	3.5	
Min	0.6	0.7	0.1	0.2	0.3	0.5	
Max	6.0	3.6	9.1	2.7	2.0	11.2	
Median	2.6	1.9	1.3	0.8	1.0	1.8	
S.D.	1.4	1.0	1.7	0.6	0.5	3.7	
N	12	10	74*	30*	21	9	157
Leaf area index (LAI)							
Mean	3.8	6.2	6.3	5.4	3.7	1.8	
Min	1.8	0.4	0.6	2.0	0.5	0.2	
Max	10.0	16.2	23.5	10.0	13.1	13.3	
Median	3.6	5.9	5.1	5.5	2.8	1.0	
S.D.	1.6	3.8	4.3	1.7	3.1	3.1	
N	37$^{(*)}$	77*	106$^{(*)}$	68*	13	17	318
Maximum rooting depth, RD_{max} (m)							
Mean	1.43	0.93	2.10	1.90			
Min	0.50	0.14	0.40	0.50			
Max	3.80	3.04	6.00	12.00			
Median	1.30	0.80	1.80	1.40			
S.D.	0.63	0.56	1.31	1.82			
N	86*	41$^{(*)}$	37*	63$^{n.s.}$			227

n.d.: no details on plant height are given for forests as these should be read of regional forest growth tables, considering site and soil conditions. Min: minimum, Max: maximum, N: number of cited values, S.D.: standard deviation. $*$ Significantly normal distribution, $P < 0.05$ ($N = 25$), $^{(*)}$ significantly normal distribution, excluding up to four outliers, $P < 0.05$ ($N = 25$). $^{n.s}$ no significantly normal distribution $P > 0.05$ ($N = 25$).

e.g. to different methods of measurement, measurement errors, extreme site or species characteristics, seasonal and annual variation, etc. Omitting these outliers, normal distribution is also valid for these five data sets at $P < 0.05$. The remaining two data sets, H_{max} of crops and RD_{max} of deciduous forest, are positively skewed and not normally distributed.

4. Continental differences in plant parameters

Most regional modelling studies should use average plant parameter values (or spans) to account for spatial and temporal heterogeneity within the land covers investigated. Information on such aggregated data is not available. Therefore, we grouped and analysed plant parameter values according to regional distribution, to give an overview and test whether significant differences exist between these regions. As a regional view on plant parameters only makes sense if a sufficient amount of data is analysed, we (i) selected and grouped parameter values for the regions of Europe and North America and (ii) took a closer look at LAI, I_c and g_s where in most cases the number of published values is $N > 8$ (Table 8). The latter is valid for 17 of the 24 analysed regional sub-data sets. Data for g_s measured in greenhouse experiments is not considered in this approach. Most striking is the lack of data for crops on LAI and I_c in North America (Table 8). As for LAI it must be assumed that we have overlooked published values. We are fairly certain that data for I_c has not been published as we considered available publications back to the beginning of the 20th century.

To prove whether average plant parameters under temperate climatic conditions in Europe and North America differ significantly, we compared means of temperate land covers by t-tests. As we showed that normal distribution for the complete set of specified plant parameters is valid, we assumed that normal distribution is also true for the regional approach. Omitting the same outliers as described above, t-test $N \geq 8$ showed no significant differences ($P > 0.05$)

Table 8
Statistics of parameter values for the main land covers in temperate ecosystems of Europe and North America

	European main land cover types				North American main land cover types			
	Crops	Herbs, forbs, grasses	Coniferous trees	Deciduous trees	Crops	Herbs, forbs, grasses	Coniferous forest	Deciduous forest
Stomatal conductance, g_s (mm s^{-1})								
Mean	5.7	5.4	1.8	4.2	4.5	5.4	2.2	4.2
Min	2.9	1.2	0.5	1.6	1.5	1.5	0.6	1.1
Max	10.0	12.5	4.0	8.5	10.4	12.5	4.8	11.7
Median	4.4	5.6	1.7	3.6	3.6	3.4	2.0	2.9
S.D.	2.6	2.7	0.9	1.8	3.1	4.3	1.0	3.1
N	12	40	19	28	8	8	25	32
Interception capacity, I_c (mm)								
Mean	2.9	1.5	1.8	1.4	1.2	1.7	2.2	1.1
Min	1.4	0.7	0.1	0.6	1.2	0.8	0.3	0.5
Max	6.0	2.4	4.7	2.7	1.2	2.8	9.1	2.0
Median	2.7	1.4	1.5	1.0	1.2	1.2	1.1	1.0
S.D.	1.3	0.9	1.2	0.9	n.d.	0.9	2.4	0.4
N	9	3	33	8	1	5	28	13
Leaf area index (LAI)								
Mean	3.7	7.2	6.2	5.8	n.d.	3.1	6.5	4.7
Min	1.8	0.5	1.1	2.5	n.d.	0.4	0.6	2.6
Max	10.0	16.2	14.0	10.0	n.d.	6.8	23.5	7.4
Median	3.6	6.7	5.0	5.7	n.d.	2.8	5.3	4.3
S.D.	1.5	3.8	3.3	1.7	n.d.	2.3	5.0	1.6
N	30	55	46	39	n.d.	16	58	20

Min: minimum; Max: maximum, N: number of cited values; S.D.: standard deviation; n.d.: no details given.

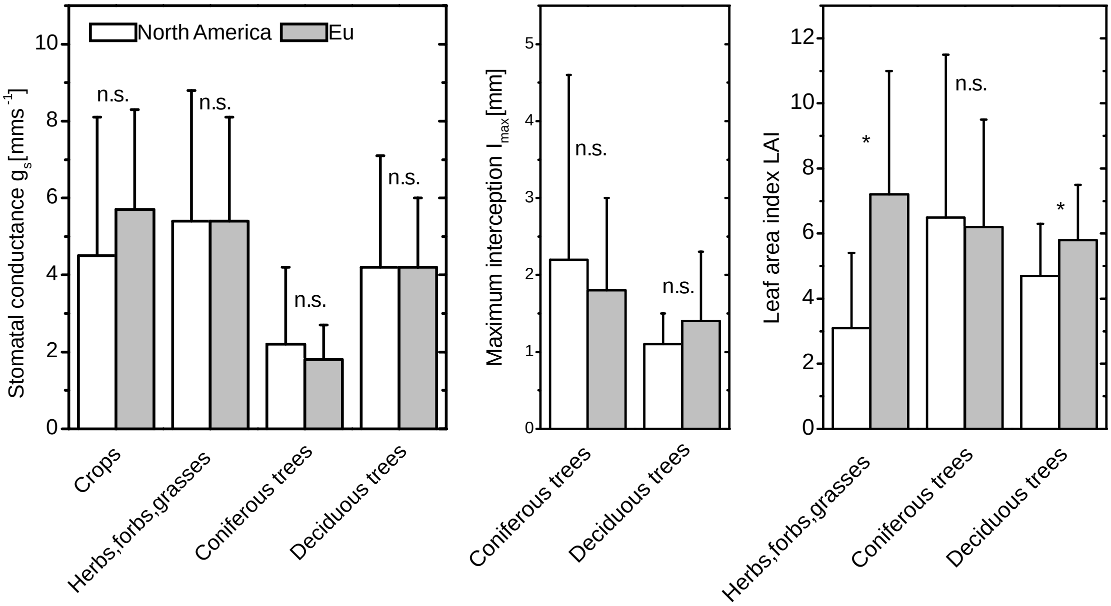

Fig. 1. Comparison of mean (±1 S.D.) plant parameter values for stomatal conductance g_s (mm s^{-1}), interception capacity I_c (mm) and leaf area index (LAI) for North American and European land cover species in temperate ecosystems. Species are divided into four main land cover crops, herbs/forbs/grasses, deciduous and coniferous trees. *t*-test was condcucted if $N = 8$ for each data set (see details in the text). $*$ denotes statistical significant differences at $P < 0.05$ and n.s. denotes no statistical significant differences at $P > 0.05$.

between North American and European land covers for interception capacity and stomatal conductance (Fig. 1, Table 8). As far as stomatal conductance is concerned, it might be concluded, that no differences in this leaf physiological property exist between species growing on the two continents, even though climatic conditions can differ substantially. No further differences could be proven for I_c of coniferous and deciduous trees. There is an information gap, especially for I_c on low-growing plant species and crops. In contrast, values for LAI were significantly different ($P < 0.05$) for pasture and deciduous forest species. It is highly probable that structural differences exist for these analysed vegetation types between North America and Europe, whereas no distinction is possible for coniferous species.

5. Conclusions

A comprehensive literature review has been performed in order to collect reliable information on various plant parameters commonly used in ecological and hydrological modelling. Time consuming and unreliable or irreproducible compilation of the described parameters of temperate land covers are no longer necessary, as an extensive overview on these plant parameters is made available. This data base provides valuable information for comprehensive uncertainty analysis such as Monte Carlo simulations (e.g. Eckhardt et al., 2003) or investigations like the climate model experiment on the influence of surface parameters on model results (www.climateprediction.com).

The majority of published plant parameter values follow normal distribution. Grouping of existing data into European and North American plant species for a continental approach revealed similar parameter ranges. Overall, hardly any statistical differences between vegetation covers of North America and Europe exists for stomatal conductance and interception capacity, whereas LAI can be distinguished for pasture and deciduous forest species. A gap in the data was found for interception measurements in low-growing plants.

A combined effort should be made to obtain sufficient information and extend the current database to other climatic zones, as for example data for tropical and sub-tropical regions is comparatively difficult to find. Modelling approaches on ecological, climatological and hydrological effects of land cover changes in these regions are of particular importance, as today main land use changes take place especially in these areas.

Further information on some of the plant parameters presented can be obtained from two recently published data bases available at the Oak Ridge National Laboratory Distributed Active Archive Center (http://www.daac.ornl.gov). Scurlock et al. (2001) collected a global data set on LAI and calculated basic statistics. Their collection covered a wide geographic distribution, including desert, tundra and tropical species, but lack detailled information on stand characteristics such as mean annual precipitation/temperature, stock density, basal area or plant height. Information on vertical root profiles was presented by Schenk and Jackson (2003), but less than 10% of the soil profiles described in their database were sampled to the maximum rooting depth. Furthermore, they published additional information such as root type, soil texture or depth of organic horizon of each soil pit under investigation, data which were not available in the literature investigated in this overview. In view of the amount and quality of information contained in the ORNL-DAAC data set and in the data base presented here, both data bases complement one another.

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