

Allometric biomass and carbon factors database

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The “Allometric, Biomass and Carbon factors” database (ABC factors database) was designed to facilitate the estimation of the biomass carbon stocks of forests in order to support the development and the verification of greenhouse gas inventories in the LULUCF sector (Land Use, Land Use Change and Forestry). The database contains several types of expansion, conversion and combined factors, by various tree species or species groups that can be used to calculate biomass or carbon of forests of Eurasian region from proxy variables (e.g., tree volume) that may come from forest inventories. In addition to the factors, and depending on the information that was available in the cited source, the database indicates: (1) the biomass compartments involved when the factor was developed; and (2) the possible applicability of the factor, e.g. by country or by ecological regions. The applicability of the factors is either suggested by the source itself, or the type of source (e.g. National Greenhouse Gas Inventory Report), or was based on the expert judgement by the compilers of the database. Finally, in order to facilitate the selection of the most appropriate of the data, the web-based interface provides the possibility to compare several factors that may come from different sources. The ABC factors database is freely available at the URL: http://afoludata.jrc.it/data_fs.cfm, in the web site AFOLU-DATA, funded and hosted by the Joint Research Centre (European Commission, DG-JRC).

Keywords: Greenhouse Gas Inventory, LULUCF, AFOLU, Climate Change, Forest Inventory, Kyoto Protocol, UNFCCC, BEF, Database.

Introduction

The United Nation Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol (KP) recognize that forest ecosystems may contribute to mitigate the human-induced greenhouse effect. In particular, Article 3.3 of the KP makes mandatory for countries that have ratified the KP to submit inventory information on the carbon stock changes and non-CO₂ emissions from afforestation (A), reforestation (R) and de-

forestation (D), whereas Article 3.4 of the KP allows countries to elect specific activities, among others forest management (FM), whose emissions and removals must also be included in the greenhouse gas inventories. All of these activities have special definition under the KP (see also the decisions of the Meetings of Parties - UNFCCC 2001), and the methodologies to estimate emissions and removals of greenhouse gases are described in various methodological guidelines by IPCC (IPCC 1997, 2003, 2006).

The greenhouse gas (GHG) inventory information, which Annex I (i.e., developed) countries have to submit to the UNFCCC secretariat annually, provides the basis for climate change policy analysis development, and for checking the compliance with Countries' commitments under the KP.

As a Party to both the UNFCCC and its KP, the European Community (EC) has to submit its annual GHG inventory. Within the EC GHG inventory system, the Climate Change Unit of the Joint Research Centre (European Commission, DG-JRC) is responsible for the Quality Assessment/Quality Control of GHG emissions and sinks in the sectors “Agriculture” and “Land Use, Land Use change and Forestry (LULUCF)”, which includes the check of Member States' inventories and the contribution to the EC

Inventory Report (EC 2004, EC 2005).

The work of JRC on the EC inventory is complemented by continuous efforts for harmonizing and improving the measuring and reporting of GHG emissions and sinks in the agriculture and forestry sector in Europe. To this aim, the JRC has established a web site “AFOLU DATA” (following IPCC 2006 the AFOLU - Agriculture, Forestry and Other Land Uses - sector consolidates the previous IPCC sectors AGRICULTURE and LU-LUCF) with the aim to offer EU-wide data sets, models and other tools to promote transparent, complete, consistent and comparable estimates of GHG emissions and removals (JRC 2005). Target users of this website are both greenhouse gas inventory practitioners and scientists (Seufert et al. 2005).

The aim of the present paper is to illustrate one of the databases hosted by AFOLU DATA clearinghouse: the “Allometric Biomass and Carbon (ABC) factors database”.

Estimating biomass carbon stock changes

Emissions or removals of CO₂ in the LU-LUCF/AFOLU sector are estimated on the basis of changes of carbon stocks in the different pools (biomass, dead organic matter, soil). With respect to forest biomass, countries must submit estimates of carbon stock changes for each inventory year.

According to IPCC (IPCC 2003, IPCC 2006) there are two basic methods to estimate carbon stock changes. In the Gain-loss method (also called: “Default method”) the carbon stock changes are estimated by considering all relevant processes, and calculated as the difference between carbon gains (due to growth of trees) and carbon losses (due to harvests, fires, and other natural losses and disturbances). By contrast, in the Stock change method, the carbon stock changes are the difference of carbon stocks for a given forest area at two points in time.

Both methods imply in practice that proxy values - such as tree or stand diameter, height and/or volume - that are available in forest inventories are converted to carbon values (Somogyi et al. 2007a). Depending on the available information on these proxy values from the forest inventories, biomass (and its changes) can be estimated using either biomass equations (Zianis et al. 2005) or various allometric, biomass and carbon factors (i.e., ABC factors).

Biomass equations are available for many tree species, ecological regions and countries as developed and published by relevant institutions, but many of them are also available in published databases (Zianis et al. 2005). If biomass is estimated using biomass equations, it should be converted to carbon stocks

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using a conversion factor (a similar method should be used when stock changes are calculated - eqn. 1):

$$C = B \cdot CF$$

where C = carbon stocks (t), B = dry biomass (t), CF = carbon fraction of biomass; $t C t^{-1}$ biomass.

In the case of ABC factors, carbon values are calculated from volume data using the following equation (eqn. 2):

$$C = V \cdot D \cdot ExpF \cdot (1 + R) \cdot CF$$

where: C = total (aboveground and belowground) amount of carbon of a tree or a forest area (tC); V = total or partial above ground volume of a tree or a forest area (m^3); D = basic density of wood ($t m^{-3}$); $ExpF$ = expansion factor to calculate total aboveground volume, or biomass, in case partial aboveground volume data is available (dimensionless); R = root-to-shoot ratio (dimensionless); CF = carbon fraction of dry wood ($tC t^{-1}$ biomass).

The above factors, and their combinations, are thus widely needed for the greenhouse gas inventories.

Several databases containing also these types of factors are freely available on the Internet - the most important being the IPCC' Emission Factor Database ("emission factor" is a coefficient that quantifies the emissions or removals of a gas per unit activity, e.g., carbon stock change per unit of forest area). Irrespective of the source utilized, the selection of a value for a specific application requires a careful evaluation of the all available information. Indeed, to fulfil the requirement that the inventory estimates "should contain neither over nor underestimates so far as can be judged, and the uncertainties in these estimates should be reduced as far as practicable" (IPCC 2000), it is fun-

damental to assess the pertinence of a given factor, or a given biomass equation, in a specific situation.

To this regard, relevant specific characteristics of the ABC Factors database are that it contains a large number of data (several hundreds of factors) in the geographical focus required (Eurasian region) that are accessible in a flexible format (i.e., it is possible to query different combinations of factors). It has also to be noticed that an effort was made to provide as much information as possible concerning the original source, complemented - when relevant and possible - with expert judgement.

Concerning the correct interpretation and use of the data included in the database, attention should be paid concerning the fact that the value of the various factors may be greatly dependent on the definition of the factors, i.e., "from what" (which variable) they expand or convert "to what" (which variable - Fig. 1; see also Somogyi et al. 2007a, Somogyi et al. 2007b). Therefore, carefully selecting the "Factor type" is crucial in correctly using the database (see below for more details).

Structure and content of the database

The ABC factors database (Somogyi et al. 2007b) is a relational SQL-database, which is freely available in the AFOLU-DATA web site (JRC 2005).

The database is structured to give the possibility both to insert data (upload mask, only for registered user), as well as to carry out queries on-line, i.e., to search for factors responding to specific characteristics (download mask, for all users). The user should carefully read the detailed on-line guidance before starting to download or upload data.

Up to now, the ABC factors database contains 1147 values from 22 countries. Conifer

forests are represented by 9 genera and 20 species, whereas the broadleaved forests by 18 genera and 11 species.

The upload mask

In Europe, policy or research based data and information on factors used to estimate greenhouse gas emissions and removal from the LULUCF sector, exist both at the national (Universities, Public or Private Research Centers) and at the Community levels (EU funded projects) but the possibility of their integrated use is often limited by the lack of a common location where it is possible to gather information on their existence, accessibility and data delivery policies.

For this reason, an objective of the ABC factors DB was to provide such a location; this was achieved by developing a dynamic web-interface (upload mask) where it is possible to input data. In order to reduce uncertainties and to increase transparencies only registered user of the AFOLU-DATA web site could provide data.

The upload mask (Fig. 2) is divided in 8 sections: (1) type of factor; (2) type of study and data source; (3) person who provided input; (4) botanical information; (5) description of study; (6) general information on representativity; (7) expand/convert "from what" - "to what" compartments; and (8) factor value.

Before uploading, the user should carefully query the database, using the download mask, to check if the data is already present in the database.

After this step the user can start with the upload procedure by filling empty text-field in each section. Moreover, in order to guarantee the harmonization of definitions some fields are provided with pull-down menu referring to other available databases and definitions (Fig. 2), like the USDA's Germplasm Resources Information Network

The figure shows two side-by-side web forms for selecting compartments. The left form is titled "expand/convert FROM what compartment *" and the right is "expand/convert TO what compartment *". Both forms have a similar structure with checkboxes for different tree compartments and input fields for "min. dbh of trees included".

Category	Options	min. dbh of trees included
aboveground living	<input type="checkbox"/> all trees	<input type="text"/>
	<input type="checkbox"/> stem	<input type="text"/>
	<input type="checkbox"/> branch	<input type="text"/>
	<input type="checkbox"/> twig	
	<input type="checkbox"/> bark	
	<input type="checkbox"/> foliage	
	<input type="checkbox"/> fruits etc.	
aboveground non-living	<input type="checkbox"/> understorey vegetation (woody below threshold, shrubs etc)	
	<input type="checkbox"/> ground vegetation (herbs grasses etc)	
aboveground non-living	<input type="checkbox"/> coarse woody debris	<input type="radio"/> down dead wood
	<input type="checkbox"/> forest floor litter (all other non-living biomass)	<input type="radio"/> harvest residues
belowground living	<input type="checkbox"/> coarse roots >2mm	
belowground living	<input type="checkbox"/> fine roots <2mm	
belowground non-living	<input type="checkbox"/> stumps	
soil carbon	<input type="checkbox"/> organic layer	
	<input type="checkbox"/> mineral soil	
	<input type="checkbox"/> peat	

Fig. 1 - Categories included in the "from what" "to what" groups, as reported in the Upload mask of the Allometric, Biomass and Carbon Factors Database.

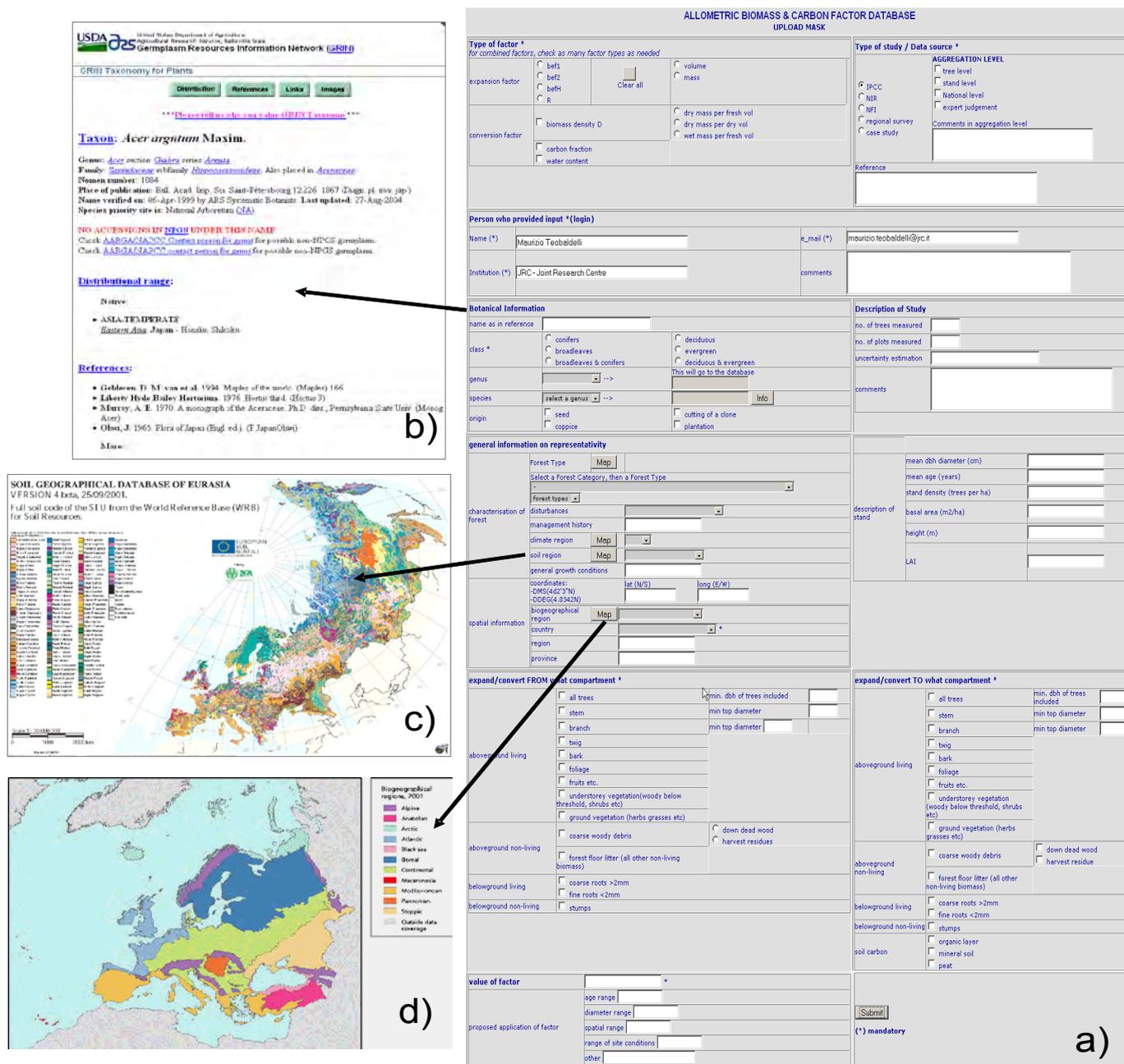


Fig. 2 - Example for the upload mask: how to input and submit data to the ABC factors database; Some fields, in the main upload mask (a), refer to other available databases like the USDA's Germplasm Resources Information Network (USDA 2008) (b), the version 4 of the Soil Geographical database of Eurasia at scale 1:1.000.000 (EUSIS 2001) (c) and the Biogeographical Regions of Europe (Roekaerts 2002) (c).

database (USDA 2008), the European forest types (Barbati et al. 2006) document, the updated World Map of the Köppen-Geiger climate classification (Kottek et al. 2006), version 4 of the Soil Geographical database of Eurasia at scale 1:1.000.000 (EUSIS 2001) and the Biogeographical Regions of Europe (Roekaerts 2002).

After submission the system provides a resume of inserted data; at that stage it is impossible for the user to correct data if any typing errors or incomplete information's occurred. If any errors occurred during the in-

put of data, the user should directly inform the database manager, reporting the record ID and the problem occurred. In any event, there is an internal revision of the data entered in order that the quality of the data is ensured.

Each data, inserted in the ABC factors database using the upload mask, are immediately available for download; for this reason, in order to help final users to download appropriate and verified data, new values will be flagged as unchecked. If the internal revision warrants it, the author will be requested

to provide additional information about the data. After the internal revision has been successfully made, the flag of the uploaded data will be changed from an unchecked to a checked status.

The download mask

In the download mask (Fig. 3) the user first needs to select the types of factors from among those contained in the database (see also Tab. 1):

- wood density: to convert volume of wood (m³) to dry weight (tons) of wood (i.e.,

Tab. 1 - Various types of factors included in the database.

Code	Meaning
BEF ₁	to expand aboveground biomass increment (dimensionless - as suggested by the GPG for LULUCF by IPCC 2003)
BEF ₂	to expand aboveground biomass stocks (dimensionless - as suggested by the GPG for LULUCF by IPCC 2003)
BEF _H	to expand harvested biomass stocks (dimensionless - as suggested by the GPG for LULUCF by IPCC 2003)
BEF _S	biomass expansion factor applicable to growing stock; transforms merchantable volume of growing stock into total above-ground volume (as suggested by IPCC 2006)
BEF _I	biomass expansion factor applicable to net annual increment; transforms merchantable volume of net annual increment into total above-ground net annual increment (as suggested by IPCC 2006).
BEF _R	biomass expansion factor applicable to wood removals; transforms merchantable removed volume into total above-ground volume removed (as suggested by IPCC 2006).
R	to estimate root biomass from aboveground biomass stocks (dimensionless)
D	wood density (t wood m ⁻³ volume)
CF	carbon fraction (tC of dry wood t ⁻¹ dry biomass)
WC	water content (%)
D*BEF ₁	D and BEF ₁ combined, <i>i.e.</i> , to convert and expand to aboveground biomass increment (t dry wood m ⁻³ fresh volume)
D*BEF ₂	D and BEF ₂ combined, <i>i.e.</i> , to convert and expand to aboveground biomass stocks (t dry wood m ⁻³ fresh volume)
D*BEF _H	D and BEF _H combined, <i>i.e.</i> , to convert and expand to harvested biomass stocks (t dry wood m ⁻³ fresh volume)
D*BEF ₁ *CF	D, BEF ₁ and CF combined, <i>i.e.</i> , to convert and expand to aboveground carbon increment (tC of dry wood m ⁻³ fresh volume)
D*BEF ₂ *CF	D, BEF ₂ and CF combined, <i>i.e.</i> , to convert and expand to aboveground carbon stocks (tC of dry wood m ⁻³ fresh volume)
D*BEF _H *CF	D, BEF _H and CF combined, <i>i.e.</i> , to convert and expand to harvested carbon stocks (tC of dry wood m ⁻³ fresh volume)
BCEF _S =D*BEF _S	D and BEF _S combined, <i>i.e.</i> , to convert and expand merchantable volume to aboveground biomass (t dry wood m ⁻³ fresh volume; as suggested by IPCC 2006)
BCEF _I =D*BEF _I	D and BEF _I combined, <i>i.e.</i> , to convert and expand merchantable volume of net annual increment to aboveground biomass growth (t dry wood m ⁻³ fresh volume; as suggested by IPCC 2006)
BCEF _R =D*BEF _R	D and BEF _R combined, <i>i.e.</i> , to convert and expand merchantable removed volume to harvested biomass (t dry wood m ⁻³ fresh volume; as suggested by IPCC 2006)
D*BEF _S *CF	D, BEF _S and CF combined, <i>i.e.</i> , to convert and expand merchantable volume to aboveground carbon (tC of dry wood m ⁻³ fresh volume)
D*BEF _I *CF	D, BEF _I and CF combined, <i>i.e.</i> , to convert and expand merchantable volume of net annual increment to aboveground carbon stocks growth (tC of dry wood m ⁻³ fresh volume)
D*BEF _R *CF	D, BEF _R and CF combined, <i>i.e.</i> , to convert and expand merchantable removed volume to harvested carbon stocks (tC of dry wood m ⁻³ fresh volume)

wood biomass);

- expansion factors: to expand from a certain amount of tree volume or biomass, which includes some, but not all tree compartments, to another one that includes more or all tree compartments. The expansion factors only include above-ground compartments (*e.g.*, to expand stem volume to total above-ground volume), whereas the so called root-to-shoot ratios are used to expand the above-ground biomass to total biomass. Note that there are expansion factors that: (1) expand tree-level data to

tree-level data; (2) that expand stand-level data to stand-level data; and (3) that expand from aggregate values (*e.g.*, commercial harvest data) to other aggregate values (*e.g.*, total biomass removed);

- Carbon fraction: to convert from biomass (t dry weight) to the amount of carbon (tC);
- Water content: to convert from fresh biomass to dry biomass;
- Combinations of the above factors (as detailed in Tab. 1).

The selection and use of these factors de-

pends first of all on the definition of both the available initial values that are to be converted and/or expanded (referred to below and in the database as “from what” values), and the final values (referred to below and in the database as “to what” values) that the user wants to calculate (Somogyi et al. 2007a). For example, to calculate the carbon content of the above-ground biomass from the stem volume, it is first necessary to multiply the stem volume with wood density to get stem biomass, then with an appropriate expansion factor to get total above-ground biomass, and

Allometric Biomass & Carbon Factor DataBase			
DOWNLOAD MASK			
TYPE OF FACTOR	COUNTRY	AGGREGATION CLASSES	
expansion factors	BEF2	conifer / broadleaves	deciduous / evergreen
Density	-	-	-
Carbon Fraction	Czech Republic	GENUS	SPECIES
Water Content	-	Fagus	-

Fig. 3 - Example of the download mask.

RESULTS SCREEN													
Date: 29-Jan-08 Time 06:49 PM - Number of records found: 133											a)		
Query: Expansion factor: BEF2 Country: Czech Republic Genus: Fagus													
Details	ID	Factor Type	Factor value	Country	PROPOSED APPLICATION OF THE FACTOR			BOTANICAL INFORMATION				Data Sources	
					Age Range	Diameter Range	Other	Aggreg. class 1	Aggreg. class 2	Genus / Species	Name as in reference		
<input checked="" type="radio"/>	1000	BEF2	1.1294	Czech Republic		45					Fagus sylvatica	European beech	Parez J., Zlabek I., Kopriva J. (1990).
<input type="radio"/>	1001	BEF2	1.1296	Czech Republic		46					Fagus sylvatica	European beech	Parez J., Zlabek I., Kopriva J. (1990).
<input type="radio"/>	1002	BEF2	1.1298	Czech Republic		47					Fagus sylvatica	European beech	Parez J., Zlabek I., Kopriva J.

FROM - TO details			
ID: 1000			
Type of Study: national survey			
Aggregation type:			
Reference: Parez J., Zlabek I., Kopriva J. (1990). Basic technical units of determining timber volume in the logging fund of the main forest species. Lesnictvi 36 (6)			
	Compartment	FROM	TO
aboveground living	All Trees		yes
	min. dbh of trees included		
	stem	yes	
	min top diameter		
	branch	yes	
	min top diameter		
	twig		
	bark		
	foliage		
	fruits etc.		
aboveground non-living	understorey vegetation (woody below threshold, shrubs etc)		
	ground vegetation (herbs grasses etc)		
	coarse woody debris		
	more details		
belowground living	forest floor litter (all other non-living biomass)		
	roots		
	coarse roots >2mm		
	fine roots <2mm		

Fig. 4 - Example of the results screen (Download mask). By clicking the radio button present in the left side of the result screen (a), a pop-up menu (b) will open showing useful information's on the biomass compartments related to the selected factor.

finally to multiply this with the carbon fraction of the biomass to get the total above ground biomass carbon. There are also combined factors in the database, which combine conversion and expansion, and allow to calculate the "to what" values in one step (Tab. 1).

In practice, there are many types of volume definitions used in the various countries. These may significantly differ depending on the compartments included (Fig. 1). Therefore, it is essential to check the definition of the volume data that is available to the user, and to select a compatible factor. To enable this selection, the database includes information on the "from what" and the "to what" data whenever this information was available in the source publication. However, it was not always possible to specify this information for each data due to lack of relevant information in the original data source. In these cases, the database contains a remark to warn the user of the unavailability of this

information. We note here that, when reporting any value that was derived using any data from the database, it is important to report the various compartments involved in the "from" and "to" categories both for the factor selected, as well as for the data for which the factor was used in order that the results be transparent.

When selecting data from the database, further considerations should also be made. Criteria of the selection, in addition to selecting the type of the factor, may include, in any order:

- the country in which the factor was developed;
- the tree species or species group (aggregation classes);

Note that, after selecting an option in a field, only the remaining options are shown in the remaining field(s).

When all the relevant criteria have been set, one or more factor values can be found in the result screen (Fig. 4).

In addition to the "factor type", "factor value" and the "country", this screen presents information on the "proposed application of the factor", the "botanical information" (which includes also the original name in the reference) and the "data source".

Regarding the applicability of the factors contained in the database, it is important to note that, in most cases, the values in the database are from case studies, which may not represent an average for a large area. The applicability of the various data from the various sources also differs because they are from different samples. The applicability of the factors is either suggested by the source itself (this suggestion is included in the database), or by the type of source (e.g., National Inventory Report or NIR), or by those that compiled the database based on their expert judgement. However, due to lack of data in most data sources, this section of the database is, unfortunately, not always filled in.

For each factor, the usefulness and the ap-

plicability of the value of the factor in a specific situation must be judged by the users themselves. As mentioned before, information on the definition of the factor is also crucial. This information is shown contained in the screen “from - to” (Fig. 4B), which appears when selecting a specific factor, and refers to various compartments involved in the “from” and “to” categories of the biomass and carbon factor selected. Consulting the original source of the data is essential, too (the full reference of the source is also included in the database).

In connection with the above it is also noted that the database contains data from several types of sources. These include the IPCC Good Practice Guidance for LULUCF (IPCC 2003) and the 2006 Guidelines (IPCC 2006) that contains the so called “default values” for broad applications. Data from the National Inventory Reports of several European countries, that may derive data from scientific studies or from expert judgements (AA. VV. 2005) are also included. Finally, data was directly taken from the scientific literature, which mainly includes results of case studies (Baritz & Strich 2000, Babos et al. 1979, Cienciala et al. 2006, MZE CR 1999, AA. VV. 2004, Giordano 1981, Karjalainen & Kellomäki 1996, Kovács 1979, Laitat et al. 2000, Lehtonen et al. 2004, Levy et al. 2004, Moltesen 1988, Schöne & Schulte 1999, Tomppo 2000, Vande Walle et al. 2005, Weiss et al. 2000, Wirth et al. 2004, ISFA 2006).

Any of these sources may contain measured data (based on volume and biomass measurements) or estimated data (based on volume and/or biomass functions). Although data were checked by the authors for inclusion or exclusion (expert judgement), some data may include errors due to using the functions mentioned.

Therefore, the applicability of the data from the various sources (including the scientific literature) is highly variable, and the user should check all the relevant references before utilizing any data from the database.

In cases when the database offers several, or when the user has other data, for a certain situation, the user may want to analyze in the application how sensitive the calculation may be to the factor applied. This may be important because information on known uncertainties could rarely be included in the database due to lack of such information in the references.

It may also happen that no data is found for a certain set of selection criteria in the database. Although the database contains more than a thousand data, this will often occur, because biomass and carbon factors are missing for many species, and/or age class, site type, etc. In this case, data for similar situations (e.g., similar species or broad categories like broadleaves, other age class,

neighbouring country, etc.), or default IPCC data might be selected (IPCC 2003, IPCC 2006). In these cases, it is up to the user to consider which data to select after a new, broader query, and to justify the use of a certain factor.

Conclusions

The database was designed to contain only data that may be relevant for the European forests, and it aims, similarly to other existing database, like the “Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species” (Jenkins et al. 2004), the “Biomass and volume equations for tree species in Europe” by METLA (Zianis et al. 2005) and the “Wood Density database” by CGIAR (2008), to integrate and extend, where possible, the databases on Emission factors realized by IPCC (2008).

Moreover, thousands of new BEF values are planned soon to be added automatically to the ABC factors database by integrating it with another database, developed in an ongoing project of JRC, the “Biomass Compartments database” (URL: http://afoludata.jrc.it/data_fs.cfm - Teobaldelli 2008). Users are also welcome to insert new data. The continuously increasing number of BEFs and their spatial distribution may help the users to identify and select appropriate and statistically significant values that are intended to be used for estimating greenhouse-gas information from forest inventories data.

As any open database, its success will depend on the inputs from the scientific/inventory communities. The data are regularly subject to quality check and the software environment to upload and download the data is subject to further development. In this context, any comment and suggestion to improve the functionality and usefulness of this database is warmly welcomed.

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