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DATA PAPER **Open Access**

Volume, increment, and aboveground biomass data series and biomass conversion and expansion factors for the main forest types of EU Member States

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Abstract

Key message This collection reports the standing stock volume, increment, aboveground biomass, and biomass conversion and expansion factors attributed to 222 forest types and 48 different management types, representative of 25 EU Member States. DOI: https://zenodo.org/records/11387301.

Keywords Standing stock volume, Increment, Aboveground biomass, BCEF, Age-class, EU

1 Background

In order to realistically represent the current growth and sink processes in forests, the traditional yield tables libraries should be replaced by empirical growth models derived from data reported by latest available National Forest Inventories (NFI), or similar data sources (e.g., published results of sampling for tree species with local representation), or estimations attached to management plans (generally based on direct field measurements). However, data collected by EU Member States are not mutually consistent at EU scale, because they are based on country-specific definitions of growing stock, biomass, and increment, which cannot be directly compared (Gschwantner et al. 2019, 2022a, b). Moreover, these data may highlight stochastic variations (or outliers) due to the effect of country-specific silvicultural practices. Despite these differences, various studies already provide a harmonized assessment of some key parameters, at least at country or sub-national level, even if these data are not scaled at species level (e.g., Alberdi et al. 2020, Gschwantner et al. 2021 and 2022a, b, Avitabile et al. 2024).

The first objective of this data paper is to provide a library of country-specific data, when possible scaled at sub-national level, reporting the standing stock volume and cumulated net annual increment (NAI) by age classes (at least for even-aged forests) for the main forest types and management types reported by each EU Member State.

To assess the forest biomass and carbon stock dynamics, the typical indicators used in forestry are the standing stock and increment in volume. The conversion of volume to biomass and carbon stock is important not only in the context of Land Use, Land Use Change and Forestry (LULUCF) reporting (Korosuo et al. 2023) but also in bioenergy studies (Březina et al. 2023). Originally, factors like biomass expansion factors (BEF, IPCC 2003) and biomass conversion and expansion factors (BCEF, IPCC 2006) were recommended, while recently the allometric models, e.g., age or volume dependent,

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are recognized as enhanced representation for the conversion of volume to biomass (IPCC 2019). Old databases and collections may not be accessible online anymore (Somogyi et al. 2008). Sampling field data requires significant effort, i.e., the number of publications related to BEF and BCEF did not increase substantially after 2010 in Europe (for example, check of "biomass conversion and expansion factor" in the publications of "Forest Ecology and Management" before and after 2012), while they increased in the rest of the world (approx. 70% of total). Meanwhile, LIDAR-based remote sensing techniques promise significant improvements, for example to assess forest aboveground volume by reconstructing 3-D tree models from point cloud data (Demol et al. 2021). Therefore, a second objective of this data paper is to provide a compilation of harmonized data of the aboveground biomass stock per unit of area and the corresponding values of BCEF used to convert the volume to dry biomass.

Throughout the paper, we try to maintain consistency of terminology used along this line: "growing/standing stock" and "increment" to anything which is reported as volume and "aboveground biomass" and "growth" to anything which is mass. Also, growing stock, standing stock, and merchantable stock are interchangeably used, in order to keep consistency to various references.

2 Methods

2.1 General modelling framework

Our processing framework includes two main workflows and various steps, summarized on Fig. 1. To compile the standing/growing stock volume (in m^3 ha^{-1}) and increment (in m^3 ha^{-1} yr^{-1}) tables, we first collected various input data reported by NFI and country reports and we classified them according to a common framework, i.e., by administrative regions, forest types, management types, and management strategies (see workflow A, on Fig. 1). Then, we assessed the consistency of these data with ancillary information reported by the literature, deriving a harmonized database. The cornerstone of this data collection is the definition of forest types, which are defined for each country according to the leading species, or species' groups (i.e., an aggregate of species, one of which is dominant), as derived by NFI data or other ancillary data sources. A detailed description of the leading species or group of species associated to each forest type is reported in the file Forest_codes.csv, reported within the data collection described within this paper (Pilli et al. 2024a). To exclude possible statistical outliers, this database was further processed through species-specific growth functions, deriving, for each EU Member State, a country-specific compilation including standardized growing stock volume and increment tables.

Within the second workflow that focuses on aboveground biomass density and BCEF, we combined the

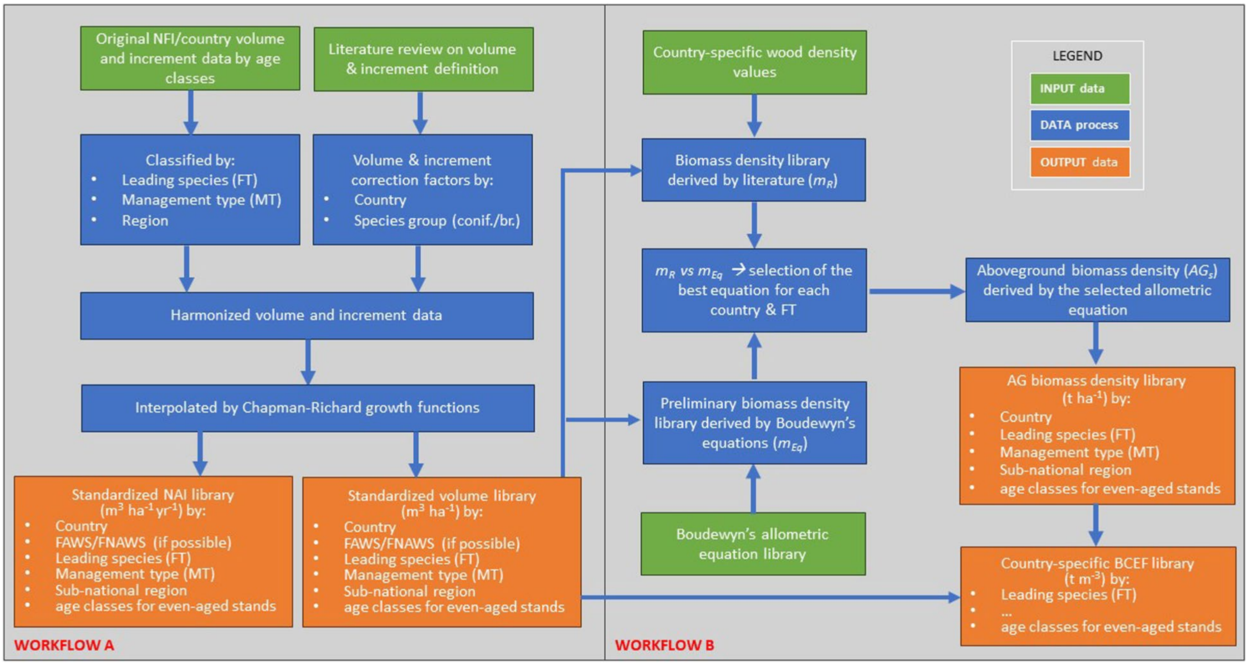


Fig. 1 Main steps applied within the present study, distinguished between the workflow A, focusing on the preparation of standing stock volume and increment data library, and workflow B, focusing on the preparation of the aboveground data and biomass conversion and expansion factors

age-class dependent standing stock volume data with two different datasets (see workflow B, on Fig. 1): the first one including country-specific data on wood density (WD) and the second one including species-specific allometric equations derived by an independent library (Boudewyn et al. 2007). By a systematic comparison between the results of these two types of estimations, we selected the best equation converting the standing volume to above-ground (AG) biomass. These equations were finally used to derive the above ground biomass density (in t dry biomass ha^{-1}) and BCEF data compilations (in t m^{-3}).

2.1.1 Standing stock volume and increment data

We collected, for each EU Member State, NFI data, reports (such as the countries' National Forestry Accounting Plans submitted as part of EU LULUCF Regulation 841/2018) and other data sources, reporting detailed standing volume and increment data on age classes (at least for even-aged stands), distinguished by leading species (or species' groups), management types, regions, and derived—when possible—from direct field measurements carried out within the period 2005–2015. As highlighted in Table 1, by focusing on this period, we could collect a relatively homogeneous set of data. Indeed, the majority of Member States (18 countries) compiled at least one forest inventory in the period between 2005 and 2010. For Greece or the Netherlands, we used information collected before 2005. For five countries, we used data collected after 2010. Thus, the entire dataset ranges between 1997 and 2017, but, taking into account the forest area reported by each country, at EU level, it can be referred, on average, to the year 2010 (Table 1).

We mostly used public NFI data, or other data sources publicly available, eventually integrated by ancillary information directly collected by the Joint Research Centre (JRC) of the EC, through bilateral contacts with countries' experts (e.g., in case of Hungary or Bulgaria), carried out within the last years (e.g., within the LULUCF annual workshops organized by JRC). Detailed information on these data sources is reported in Pilli et al. 2024b. This activity was carried out as part of the calibration and updating effort of the JRC forest carbon model (EU-CBM-HAT), an enhanced forest carbon model made available by the JRC (Blujdea et al. 2022).

All data sources were systematically revised according to a common classification system, aiming to define the forest type (FT, as defined above), and the main management types (MT) reported at national level, when possible, further scaled at sub-national (i.e., NUTS 2) level and eventually distinguished between forest area available (FAWS) and not available (FNAWS) for wood supply. For most of the countries, MT essentially distinguishes coppices and high forests, further distinguished between even-aged and uneven-aged management strategies (MS). A complete list of the classification system applied to each country is reported within the data base *Volume_increment_database* (see below). Since we could not collect sufficient information for Malta and Cyprus, these countries were excluded from any further analysis.

To avoid possible inconsistencies due to different definitions used at national level, volume and increment data need to be further harmonized according to a common definition. For this reason, we excluded all non-stem woody components from the volume data, i.e., branches, top, stump and bark, eventually accounted for within the original NFI data. To harmonize original input data, we collected from the NFI and from the literature (Gschwantner et al. 2019, 2022a, b) specific information on bark, small and main branches, and top and stump included within the country's definition of volume (see Table 1).

As is the case for standing stock volume, increment data reported by NFI can also include various biomass components. At times, the data may only include the merchantable biomass, while at others, it may also include other compartments, with varying theoretical definitions. According to specific work performed by the JRC in collaboration with the European National Forest Inventory Network (ENFIN), hereafter referred to as SC20 and SC21 (reported as Gschwantner et al. 2021 and 2022a, b), most of the increment values reported by NFI refer to the gross annual increment (GAI). For these cases, the GAI was scaled to net annual increment (NAI), excluding annual natural losses (ANL), which are due to natural mortality processes. As was done for the procedure to harmonize volume, we first assessed the various biomass components included within the definition of increment applied at national level, and, if needed, we excluded ANL. When possible, we based our assessment on the information reported (for 10 Member States) within the SC20 and SC21 (see also Avitabile et al. 2023), and we harmonized the original increment values by applying, to each country, specific correction factors (see Table 1). For the remaining countries, we estimated the increment correction factors based on ancillary information reported by the literature and according to an expert assessment.

Based on such pre-processing, we applied specific correction factors (reported on Table 1) to the original volume and increment data series collected by countries, in order to exclude bark and other non-merchantable biomass components from volume data and ANL from gross annual increment data.

We posit that, although the correction factors were initially derived from information reported in the literature,

Table 1 Woody biomass components included within the national definition of biomass considered by each data source, and corresponding correction factor applied to broadleaves and coniferous species, for volume and increment data. The final correction factor reported on this table is partially based on the analysis of information reported by the literature (i.e., Gschwantner et al. 2019) and partially derived from an ex-post adjustment performed by JRC

Country	NFI reference year	Area (kha)	Woody biomass components included within original data source						Reference	Volume correction factor		Increment correction factor	
			Stem	Bark	Branches		Top	Stump		Conif	Broadl	Conif	Broadl
					Large	Small							
AT	2008	3,992	X	X			X		[1]	0.85	0.85	0.75	0.69
BE	2008	623	X	X	X				[1]–[2]	0.78	0.68	0.88	0.88
BG	2010	3,737	X	X					[3]	0.85	0.85	0.85	0.85
CY	-	-	-	-	-	-	-	-	-			-	-
CZ	2009/17	2,530	X	X	X				[1]	0.82	0.82	0.90	0.90
DE	2011/12	10,520	X	X	X[B]			X	[1]	0.88	0.83	0.86	0.86
DK	2013	591	X	X	X[B]	X[B]	X	X	[1]	0.83	0.83	0.75	0.75
EE	2010	2,086	X	X			X		[1]	0.86	0.86	0.70	0.70
ES	2004-18‡	18,343	X	X					[1]–[2]	0.88	0.88	0.40	0.40
FI	2009/13	20,267	X	X			X		[1]	0.83	0.83	0.85	0.54
FR	2006/10	15,406	X	X				X	[1]	0.85	0.85	0.90	0.90
GR	< 2000	3,079	X	X	?				[3]	0.60	0.60	0.65	0.65
HR	2005	1,860	X	X	X			X	[2]	0.73	0.73	0.76	0.76
HU	2015	1,870	X	X	X				[1]–[2]	0.70	0.70	0.70	0.70
IE	2005	614	X	X	X[B]				[1]–[4]	[4]	[4]	[4]	[4]
IT	2005-(15)	8,582	X	X	X				[2]	0.85	0.85	0.64	0.64
LT	2010/14	2,119	X	X			X	X	[1]	0.85	0.85	0.65	0.65
LU	2010	85	X	X	X				[2]	0.88	0.88	0.88	0.88
LV	2004/08	3,176	X	X			X		[1]	0.86	0.86	0.60	0.60
MT	-	-	-	-	-	-	-	-	-			-	-
NL	1997–03	307	X	X	?				[2]	0.82	0.82	0.82	0.82
PL	2010/14	9,178	X	X					[2]–[3]	0.85	0.85	0.88	0.88
PT	2015	3,210	X	X	X[V]		X[V]	X[V]	[1]–[2]	0.75	0.75	0.90	0.90
RO	2010	6,421	X	X	X	X	X		[1]–[3]	0.65	0.52	0.70	0.70
SE	2010	21,761	X	X			X		[1]	0.85	0.85	0.72	0.72
SI	2009	1,186	X	X	X				[1]	0.83	0.83	[4]	[4]
SK	2010	1,908	X		X				[1]	0.96	0.96	[4]	[4]

[1] Gschwantner et al. (2019)

[2] NFI or other country's data sources

[3] JRC assumption based on empirical assessment (no specific information available)

[4] Use of country's specific data or JRC data already corrected

[B] Only for broadleaves species

[V] Various assumptions based on species (see [1])

the final values applied at the country level were based on expert assessment, which also included an ex-post validation of the final results against ancillary information reported in the literature.

To factor out possible outliers, due to the stochastic disturbance events affecting forest inventories data, and to aggregate unrepresentative data (i.e., for forest types with few volume/increment data), the data produced within the previous step was interpolated, for each country and group of classifiers, through a Chapman-Richard function (or other exponential and power functions). At this purpose, we used the Marquardt method provided by the SAS®software (Motulsky and Ransnas 1987). In this way, we derived country-specific volume curves reporting, for each set of classifiers defined at country level, the average standing volume and net annual increment per unit of area on age-classes of 10 years (at least for even-aged stands). Most of the original dataset included data on the standing volume by main species (or species' groups) and, for even aged stands, by age classes. When the distribution of volume on age classes was not available, we derived the volume curves from a predetermined collection, based on a large literature review on previous EU studies (see Pilli et al. 2013, 2016). In this case, we selected the curve that minimizes the relative difference with the average volume reported at country level within the same age class interval reported by original data sources from this library. In a few cases, where no data was available, we used growth curves applied to other comparable countries or similar FTs.

Similarly, when the distribution of increment versus age classes was not available, we derived the growth curves from a predetermined library, with the same approach applied to the volume growth curves. In a few cases, also for the increment data, where no data was available, we used the data derived from other comparable countries or similar FTs.

When relevant at country level, volume and increment data were also used to infer the average merchantable standing volume and NAI assigned to uneven-aged stands, where possible on sub-national scale. In this case, original data were harmonized by applying the same correction factors used for even-aged stands, but they were not classified by age classes.

The result of this workflow includes two libraries reporting, for each Member State, FT, MT, MS and, in most cases, region (defined, when possible, at NUTS 2 level), a harmonized set of volume and net annual increment data, further distinguished, for even-aged stands, by age classes. In a few cases (i.e., for Austria, Finland and Sweden), data were also distinguished between FAWS and FNAWS, combining the information reported by country data sources, with an ancillary harmonized assessment of the forest area available for wood supply made available by the JRC (see Avitabile et al. 2023).

2.1.2 Aboveground biomass density and biomass conversion and expansion factors (BCEF)

Generally speaking, there are two solutions to convert volume to biomass: one relies on biomass conversion factors, the other, on dynamic, size-dependent allometric equations (e.g., Brown 2002). The first one, based on factors, involves general assumptions, i.e., uniform wood density and generally applicable BEFs values, e.g., discontinuous values on ranges/classes of age or volume. The dynamic one is very demanding in terms of sampled data to derive robust models of conversion but reflects the stand's structural harmony in the bioaccumulation process in all biomass components better. In our reported datasets we included both these approaches, as follows.

1. For each country, we first associated to each FT, species-specific WD values, based on country-specific data reported by the literature or derived from similar species for comparable countries. WD reported by the literature are generally based on sampling and measurements. By definition, wood density represents a standardized coefficient reporting the ratio between the oven-dry mass of a wood sample and its fresh volume. Based on these parameters, we estimated the merchantable biomass density associated to each age class and FT, using the harmonized volume data collected within the previous step. The data inferred from these WD values were used as reference biomass library (m_R).
2. We derived a second biomass library (m_{Eq}) by combining our harmonized volume database with 893 species-specific allometric equations, built on volume dependent logistic models and based on direct field measurements collected by the Canadian Forest Service on 83 different species (Boudewyn et al. 2007). For each equation, the original database includes a specific set of parameters converting the merchantable volume to biomass and other ancillary equations to add the non-merchantable tree components (bark, branches, foliages). Since sapling-sized trees are generally excluded from NFI direct field measurements, we attributed zero to them in our exercise.
3. For each country and FT, we systematically compared m_R and m_{Eq}, and we selected the allometric equation that best represents the volume to biomass conversion, according to three subsequential criteria. We first selected a sub-set of m_{Eq} equations showing the smallest root mean square error (RMSE) between m_R and m_{Eq}; then, we excluded from this sub-set, the equations where the fraction of stem wood to total aboveground biomass was not consistent with values provided by literature (or derived by an expert assessment) for the same leading species associated to each FT; finally, we considered other taxonomic criteria, prioritizing the selection of allometric equations derived from the same species or genus or group of species (i.e., distinguishing coniferous and non-coniferous species groups).
4. Since allometric equations directly convert the merchantable volume to total aboveground biomass, they implicitly include assumptions on wood density and the model output can be also used to back-calculate BEF and WD values (Kurz et al. 2009). In this case, the selected equation was used to derive the AG

biomass density by FT and age class and the corresponding BCEF was estimated as:

$$BCEF = \frac{AG_s}{V_m} \tag{1}$$

where V_m is the merchantable volume reported by our growth curve library for each FT and age class, and AG_s is the corresponding AG biomass density estimated by the allometric equation selected within previous step. In few cases (about 76 out of 56.4 k records), the biomass attributed to foliages by the final allometric equation associated to each FT was considered as not consistent with the corresponding stem biomass component (i.e., the ratio between the biomass estimated for foliages and stem > 100%, or 300% for the first age class). In these cases, foliages were excluded from the computation of the total AG biomass and of the corresponding BCEF (see *Read_me.txt* on the *Vol_to_biomass_BCEF_databse*).

The script used for the selection of best volume-to-biomass equation (selection_param_Boudewyn_eqs.py) is included in the Notebooks downloadable within the data page: https://pypi.org/project/eu-cbm-hat/.

2.2 Access to the data and metadata description

This paper includes the following database, freely accessible through a Zenodo data collection (Pilli et al. 2024a), named "EU volume, increment, aboveground biomas,s and BCEF libraries":

1. Volume and increment database, reporting the merchantable standing volume (in $m^3\ ha^{-1}$ u.b.) and the net merchantable volume increment (in $m^3\ ha^{-1}\ yr^{-1}$ u.b.) of forest types identified at country level. All data, when possible, were further classified by regions, management systems, and distinguished between FAWS and FNAWS. For even-aged forest stands, data were further distinguished by age classes. All data and further details on the classifiers are reported within the folder *Volume_increment_database.*
2. Aboveground biomass and BCEF database, reporting the total aboveground dry biomass (in $t\ ha^{-1}$) of the forest types identified at country level, further distinguished, for even-aged stands, by age classes. All data were further classified by regions, management systems, and, when possible, distinguished between FAWS and FNAWS, according to the same classification system applied within the volume and increment database. The total aboveground dry biomass is further distinguished between the following components: stem (i.e., merchantable wood biomass excluding bark), bark, branches (including both main and small branches), and foliages. The database also reports the biomass conversion and expansion factors (BCEF, in $t\ m^{-3}$) derived from the ratio between the merchantable volume associated to each record and the corresponding total aboveground biomass. All data and further details are reported within the folder *Vol_to_biomass_bcef_database.*
3. An ancillary database (*Vol_to_biomass_parms_JRC_selection*), including ancillary information on the parameters defining the allometric equations associated to each FT and group of classifiers as defined above (see Boudewyn et al. 2007 for detail information on allometric equations models used within the present paper).

A detailed description of all input data and of the classification scheme applied within this study is reported in Pilli et al. (2024a), within the *Volume_increment_database*, available at https://doi.org/10.5281/zenodo.11387301.

Detailed information on the data sources used for each country are reported as Annex 1, in Pilli et al. (2024b).

2.3 Technical validation

We validated our results against other studies including both a harmonization effort of the same statistics (i.e., including a harmonization of definitions and concepts, as defined by Rennolls et al. 2009) and a temporal alignment of various data sources. The volume and carbon stock statistics reported by the DIABOLO study (Vauhkonen et al. 2019a), and the volume increment statistics reported by Avitabile 2023, include data referred to the same year, in this case 2015, which were preliminarily harmonized to a common base definition, consistent with our analysis.

Such as in other studies, also our data were not fully aligned in time even if they mostly refer to the period 2005–2015. To align our dataset to a common base year, we used the same approach applied by Vauhkonen et al. (2019a), and we initialized a yield data driven forest model, with our volume and increment growth curves. We used the *EU-CBM-HAT* model developed by the JRC (Blujdea et al. 2022), and we ran it, for each country, until a common base year (in this case 2015) starting from the base year assigned to the original data sources (see Table 1). Ancillary input data needed for the model initialization were generally inferred from the same data sources used to derive the growth curve libraries (Pilli et al. 2024b). Then, we derived from the model output the same statistics reported by other data sources. When referred to FAWS, total aboveground volume and C stock have a good fit with other data sources (see Figs. 2 and 3). Data on FNAWS are clearly affected by the lack of specific information made available at country level (for most countries we could not distinguish FAWS and

FNAWS, so FAWS assumptions were applied also to FNAWS). Increment data generally have a good fit both when scaled against the total forest area and against the FAWS (Fig. 4).

Data on average WD and BCEF derived by model output were compared with (i) the ratio between the total aboveground biomass stock and stemwood volume derived by DIABOLO, as reported by Vauhkonen et al. (2019b) dataset (Fig. 5, plot A) and (ii) the ratio between the merchantable volume and total biomass stock derived by the State of Europe's Forests data (Forest Europe 2020, hereafter referred as SoEF) (Fig. 5, plot B). The comparison on WD values highlights that DIABOLO data are generally higher than our WD. This can be because, for DIABOLO, the WD was estimated as the ratio between total aboveground biomass (including stemwood, logging residues, and stumps) and stemwood volume, defined as the part of tree stem from the felling cut to the tree top,

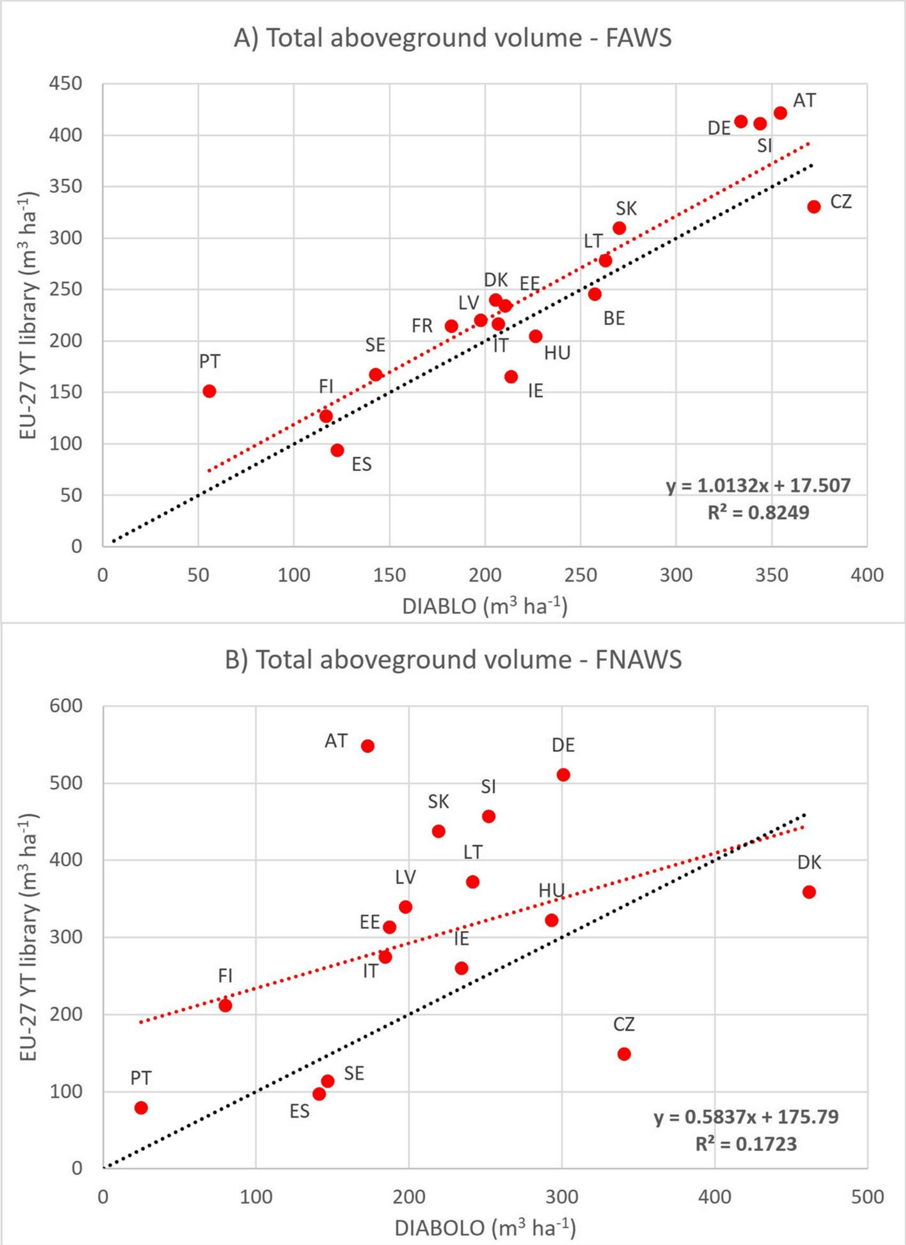
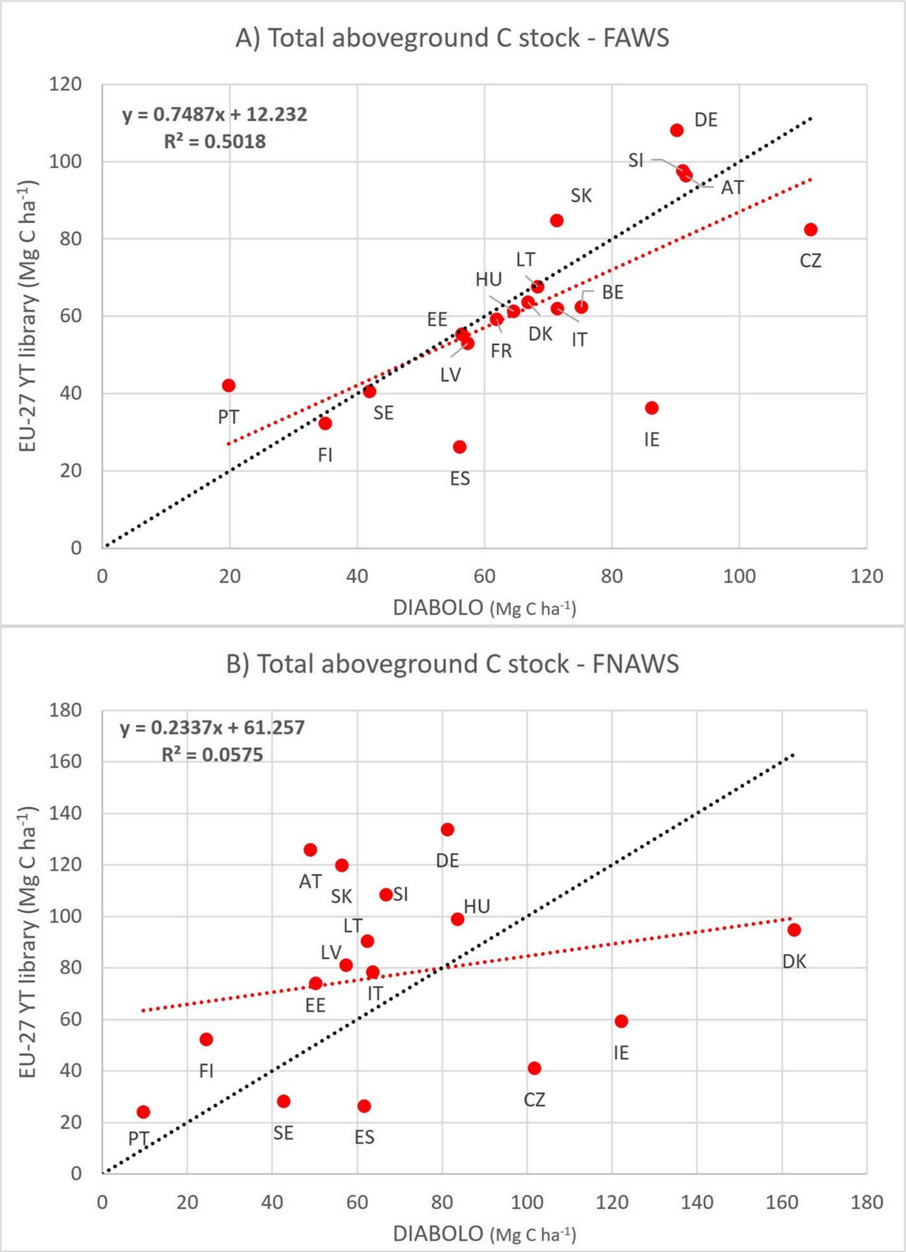


Fig. 2 Regression plot between the total aboveground volume (referred to FAWS on plot A and FNAWS on plot B) derived by our yield table libraries (on the *y*-axis, using EU-CBM-HAT) and reported by DIABOLO project (Vauhkonen et al. 2019b) on the *x*-axis. The black dot line is the one-to-one regression line. All values are referred to 2015 and each dot refers to a specific country, reported as label


A) Total aboveground C stock - FAWS

B) Total aboveground C stock - FNAWS

Fig. 3 Regression plot between the total aboveground C stock (referred to FAWS on plot A and FNAWS on plot B) derived by our yield table libraries (on the *y*-axis, using EU-CBM-HAT) and reported by DIBOLO project (Vauhkonen et al. 2019b) on the *x*-axis. The black dot line is the one-to-one regression line. All values are referred to 2015 and each dot refers to a specific country, reported as label

including removed branches. Therefore, the two components, in some cases, could not be fully comparable, and, for this reason, countries' WD values derived by DIABOLO seem to be higher than most of the WD values reported for the main European species by other data sources, such as IPCC (IPCC 2006) or Vieilledent et al. (2018). In the same way, in some cases, BCEF derived by SoEF seems to be quite high, compared to the IPCC ones, such as for example in case of Bulgaria and Spain, where they are equal to 0.86 and 0.92, respectively.

3 Reuse potential and limits

This compilation can be used both as direct input for calibrating yield-data driven models applied both at national and international level, either for directly assessing the current and potential growth or net carbon sink of

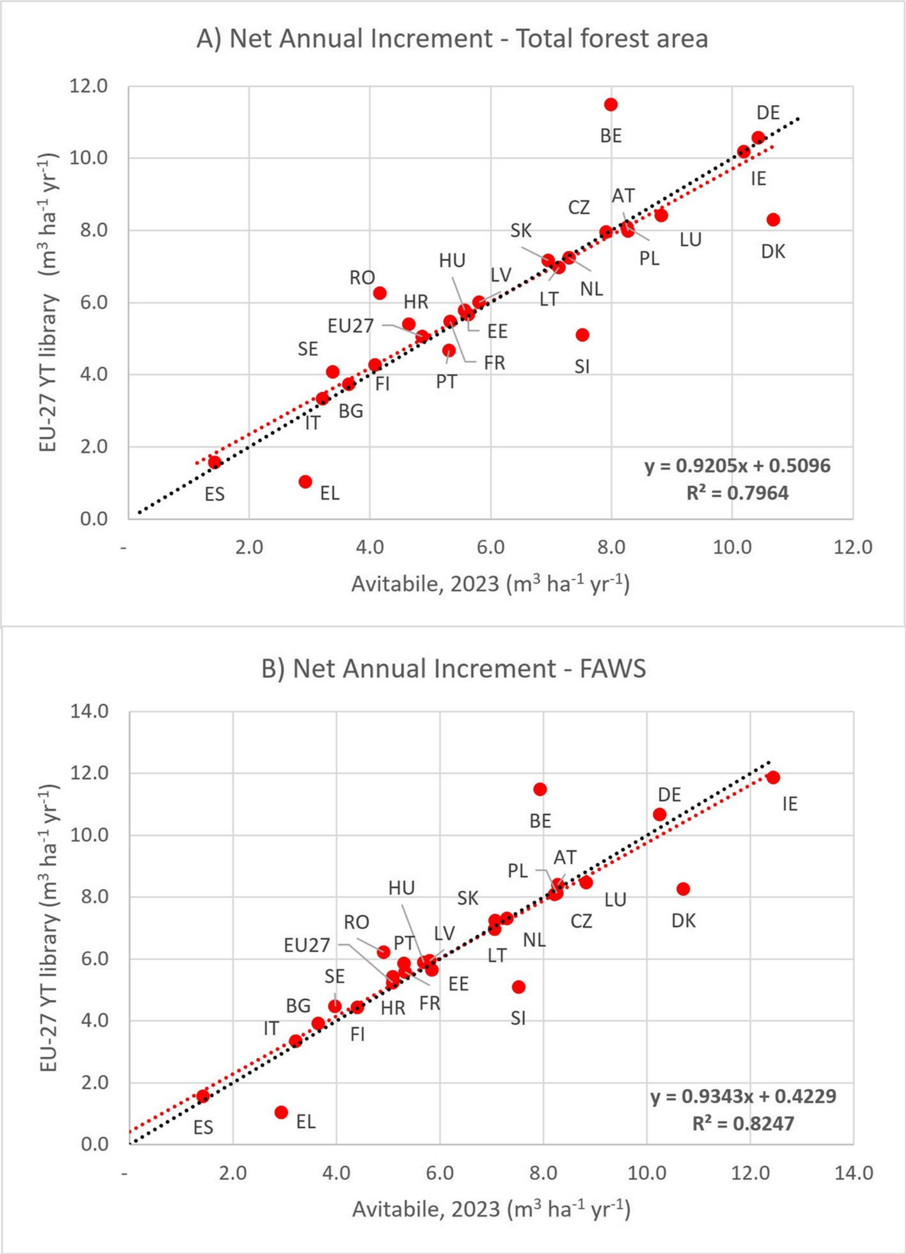


Fig. 4 Regression plot between the Net Annual Increment values (referred to the total forest area on plot A and to FAWS on plot B) derived by our yield table libraries (on the *y*-axis, using EU-CBM-HAT) and reported by Avitabile (2023) on the *x*-axis. The black dot line is the one-to-one regression line. All values are referred to 2015 and each dot refers to a specific country, or to EU-27, reported as label

specific forest area, also at sub-national level. This is part of climate policy preparation, implementation and compliance checks (Korosuo et al. 2023, Vizzarri et al. 2021). Consequently, this exercise supports the implementation of the JRC forest carbon model EU-CBM-HAT (Pilli et al. 2024b; Blujdea et al. 2022).

An important highlight is that, despite age class is mentioned as a driver in the whole analysis, a key element addressed by our assessment is also given by the reciprocal consistency between biomass, volume, and increment data, associated to each forest type.

Since these data set provide volume, increment, and biomass data per unit of area, these values can be directly combined with other information reporting the forest area, as made available also from remote sensing data.

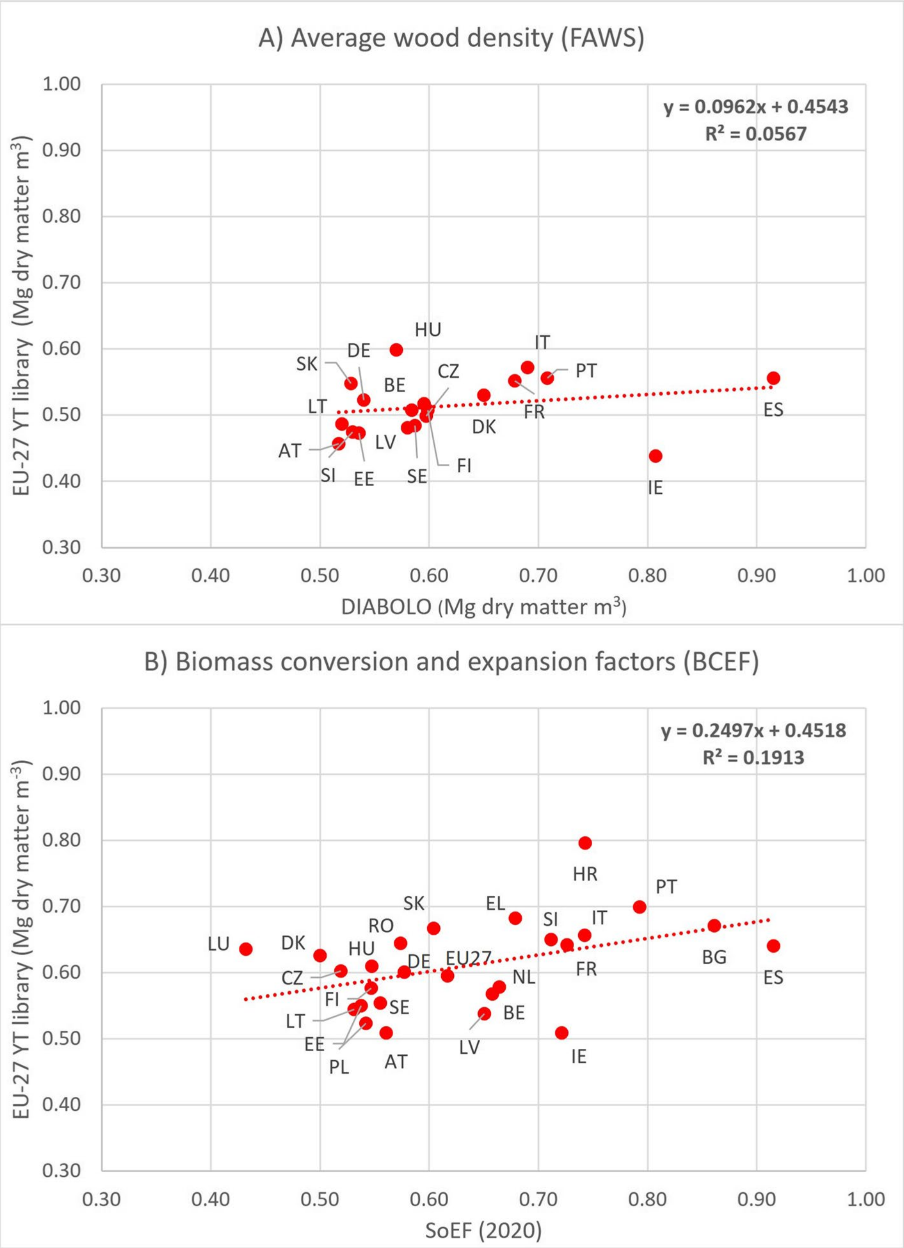


Fig. 5 Comparison between: plot A, the average wood density derived by our yield table libraries (on the *y*-axis, using EU-CBM-HAT) and inferred from DIABOLO data base (Vauhkonen et al. 2019b) on the *x*-axis; plot B, the average Biomass conversion and expansion factor derived by our yield tables libraries (on the *y*-axis, using EU-CBM-HAT) and inferred from SoEF (Forest Europe 2020), on the *x*-axis. Each dot refers to a specific country, or to EU-27, reported as labels

Even if the original data have been interpolated to exclude possible outliers, and further checked to ensure the overall consistency of the final output, because of the small number of input data reported for some country and FT, and the large number of records reported within the final database (about 57 k, distributed between 25 countries, 222 FT, various MT and MS, and 20 age classes), in some cases, the final results may include some volume or increment values not consistent with the age class distribution. This is the case, for example, of some volume data attributed to the first age class, clearly overestimated (e.g., for the forest type LD in Italy), or to the final age classes. For these reasons, before using these data at local level, we recommend proceeding to a further expert assessment, including a systematic comparison—and, eventually, recalibration—of volume and increment data reported within the present collection, with similar information made available at local level (e.g., provided by forest management plans or collected by NFI plots). We also stress that, because of the lack of data made available at country level, only in few cases (Finland and Sweden) volume and increment data are specifically referred to FNAWS. For most of Member States, we could not distinguish FAWS and FNAWS.

The JRC is continuously working, in collaboration with MS, to collect new information made available by NFI and national institutions. Therefore, both these collections can be further updated, and refined, according to these new data.

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Authors' contributions
RP and VB designed the study and analyzed the data, in collaboration with PR. RP and VB wrote the paper, in collaboration with PR, GG, and SM. All authors read and approved the final paper.

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Availability of data and materials
The datasets generated and analyzed during the current study and the data collection are available in a Zenodo repository, accessible at the following link: https://zenodo.org/records/11387301.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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