CHAPTER 4

FOREST LAND

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Soil Carbon Sections were prepared by lead authors, S. Niinistö, A. Lehtonen, Å. Kasimir, and S.M. Ogle.

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No refinement.

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No refinement.

4.2.3 Soil carbon

This section elaborates on estimation procedures and *good practices* for estimating change in forest soil C stocks. It does not include forest litter, which is a dead organic matter pool. Separate guidance is provided for two types of forest soils: 1) mineral forest soils, and 2) organic forest soils.

The organic C content of mineral forest soils (to 1 m depth) typically varies between 20 to over 300 tonnes C ha^{-1} depending on the forest type and climatic conditions (Jobbagy and Jackson, 2000). Globally, mineral forest soils contain approximately 700 Pg C (Dixon *et al.*, 1994), but soil organic C pools are not static due to differences between C inputs and outputs over time. Inputs are largely determined by the forest productivity, the decomposition of litter and its incorporation into the mineral soil and subsequent loss through mineralization/respiration (Pregitzer, 2003). Other losses of soil organic C occur through erosion or the dissolution of organic C that is leached to groundwater or loss through overland flow. A large proportion of input is from above-ground litter in forest soils, so soil organic matter tends to concentrate in the upper soil horizons, with roughly half of the soil organic C in the upper 30 cm layer. In some forest ecosystems, rooting zones of trees extend considerable deeper than 30 cm, which can increase the share of soil organic carbon in deeper layers (Nepstad *et al*., 1994). Changes in soil carbon stocks in response to management actions such as thinning and clear-cutting have been detected below 20–30 cm, but not in all studies or all depths (Achat *et al*., 2015a; James and Harrison, 2016; Gross *et al*., 2018). Moreover, the scarcity of measurements increases uncertainty related to soil carbon stock changes deeper in soil. The C held in the upper profile is often the most chemically decomposable, and the most directly exposed to natural and anthropogenic disturbances. This section only deals with soil C and does not address decomposing litter (i.e., dead organic matter, see Section 4.2.2).

Human activities and other disturbances such as changes in forest type, productivity, decay rates and disturbances can alter the C dynamics of forest soils. Different forest management activities, such as rotation length; choice of tree species; drainage; harvest practices (whole tree or sawlog, regeneration, partial cut or thinning); site preparation activities (prescribed fires, soil scarification); and fertilization, affect soil organic C stocks (Harmon and Marks, 2002; Liski *et al.*, 2001; Johnson and Curtis, 2001). Changes in disturbance regimes, notably in the occurrence of severe forest fires, pest outbreaks, and other stand-replacing disturbances are also expected to alter the forest soil C pool (Li and Apps, 2002; de Groot *et al.*, 2002). In addition, drainage of forest stands on organic soils reduces soil C stocks.

General information and guidelines on estimating changes soil C stocks are found in Chapter 2, Section 2.3.3, and needs to be read before proceeding with the specific guidelines dealing with forest soil C stocks. Changes in soil C stocks associated with forests are computed using Equation 2.24 in Chapter 2, which combines the change in soil organic C stocks for mineral soils and organic soils; and stock change for soil inorganic C pools (Tier 3 only). This section elaborates on estimation procedures and *good practices* for estimating change in forest soil C organic stocks (Note: It does not include forest litter, i.e., dead organic matter). Separate guidance is provided for two types of forest soils: 1) mineral forest soils, and 2) organic forest soils. See Section 2.3.3.1 for general discussion on soil inorganic C (no additional information is provided in the Forest Land discussion below).

To account for changes in soil C stocks associated with *Forest Land Remaining Forest Land*, countries need to have, at a minimum, estimates of the total Forest Land area at the beginning and end of the inventory time period, stratified by climate region and soil type. If land-use and management activity data are limited, Approach 1 activity data (see Chapter 3) can be used as the basis for a Tier 1 approach, but higher Tiers are likely to need more detailed records or knowledge of country experts about the approximate distribution of forest management systems. Forest Land classes must be stratified according to climate regions and major soil types for Tier 1, which can be accomplished with overlays of suitable climate and soil maps. Further stratification may be useful for development of Tier 2 or 3 methodology for a country.

4.2.3.1 CHOICE OF METHOD

Inventories can be developed using Tier 1, 2 or 3 approaches, and countries may choose to use different tiers for mineral and organic soils. Decision trees are provided for mineral soils (Figure 2.4) and organic soils (Figure 2.5) in Chapter 2 to assist inventory compilers with selection of the appropriate tier for their soil C inventory.

Mineral soils

In spite of a growing body of literature on the effect of forest types, management practices and other disturbances on soil organic C, the available evidence remains largely site- and study-specific, but eventually may be generalized based on the influence of climatic conditions, soil properties, the time scale of interest, taking into consideration sampling intensity and effects across different soil depth increments (Johnson and Curtis, 2001; Hoover, 2003; Page-Dumroese *et al.*, 2003). However, the current knowledge remains inconclusive on both the magnitude and direction of C stock changes in mineral forest soils associated with forest type, management and other disturbances, and cannot support broad generalizations.

Tier 1

Current scientific basis is not sufficient to develop Tier 1 default emission factors for quantification of effects of forest management by IPCC climate zones. Thus, it is assumed in the Tier 1 method that forest soil C stocks do not change with management. Recent studies indicate, that effects of forest management actions on soil C stocks can be difficult to quantify and reported effects have been variable and even contradictory (see Box 4.3a). Furthermore, if using Approach 2 or 3 activity data (see Chapter 3), it is not necessary to compute C stock changes for mineral soils (i.e., change in SOC stocks is 0). If using activity data collected via Approach 1 (see Chapter 3), and it is not possible to identify the amount of land converted *from* and *to* Forest Land, then the inventory compiler should estimate soil C stocks for Forest Land using the areas at the beginning and the end of the inventory period in order to estimate the change in soil carbon stock. The changes in soil C stocks for Forest Land are summed with the changes in stocks for other land uses to estimate the influence of land-use change. If the compiler does not compute a stock for Forest Land, it is likely to create systematic errors in the inventory. For example, land converted from Forest Land to Cropland or Grassland will have a soil C stock estimated in the final year of the inventory, but will have no stock in the first year of the inventory (when it was forest). Consequently, conversion to Cropland or Grassland is estimated as a gain in soil C because the soil C stocks are assumed to be 0 in the Forest Land, but not in Cropland and Grassland. This would introduce a bias into the inventory estimates. SOC_0 and SOC_{0-T} are estimated for the top 30 cm of the soil profile using Equation 2.25 (Chapter 2). Note that areas of exposed bedrock in Forest Land are not included in the soil C stock calculation (assume a stock of 0). Further clarification on soil organic carbon estimation is presented in Section 2.3.3.1.

Tier 2

Using Equation 2.25 (Chapter 2) soil organic C stocks are computed based on reference soil C stocks and country-specific stock change factors for forest type (F_I), management (F_{MG}) and natural disturbance regime (F_{ND}). Note that the stock change factor for natural disturbance regime (F_{ND}) is substituted for the land-use factor (F_{LU}) in Equation 2.25. In addition, country-specific information can be incorporated to better specify reference C stocks, climate regions, soil types, and/or the land management classification system.

Tier 3

Tier 3 approaches will require considerable knowledge and data allowing for the development of an accurate and comprehensive domestic estimation methodology, including evaluation of model results and implementation of a domestic monitoring scheme and/or modelling tool. The basic elements of a country-specific approach are (adapted from Webbnet Land Resource Services Pty ltd, 1999):

- Stratification by climatic zones, major forest types and management regimes coherent with those used for other C pools in the inventory, especially biomass;
- Determination of dominant soil types in each stratum;
- Characterization of corresponding soil C pools, identification of determinant processes in SOC input and output rates and the conditions under which these processes occur; and
- Determination and implementation of suitable methods to estimate carbon stock changes from forest soils for each stratum on an operational basis, including model evaluation procedures; methodological considerations

are expected to include the combination of monitoring activities – such as repeated forest soil inventories - and modelling studies, and the establishment of benchmark sites. Further guidance on good soil monitoring practices is available in the scientific literature (Kimble *et al.*, 2003, Lal *et al.*, 2001, McKenzie *et al.*, 2000). It is *good practice* for models developed or adapted for this purpose to be peer-reviewed and validated with observations representative of the ecosystems under study and independent from the calibration data.

More guidance on Tier 3 methods is given in Chapter 2.3.3.1, such as examples of Tier 3 modelling methods in Box 2.2d. The examples provide information about types of data required, brief descriptions of models, methods that are used to apply the models, and how using a Tier 3 model has changed results. General guidance on measurement-based and model-based Tier 3 inventories for the AFOLU sector can be found in Section 2.5.

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.2.

4.2.3.2 CHOICE OF STOCK CHANGE AND EMISSION FACTORS

Mineral soils

Tier 1

It is not necessary to compute the stock estimates for *Forest Land Remaining Forest Land* with Approach 2 or 3 activity data (see Chapter 3). If using Approach 1 activity data, stock change factors, including input, management and disturbance regime, are equal to 1 using the Tier 1 approach. Consequently, only reference C stocks are needed to apply the method, and those are provided in Table 2.3 of Chapter 2.

Tier 2

In a Tier 2 approach, stock change factors are derived based on a country-specific classification scheme for management, forest types, and natural disturbance regimes. A Tier 2 approach should include the derivation of country-specific reference C stocks, and a more detailed classification of climate and soils than the default categories provided with the Tier 1 method. The depth for evaluating soil C stock changes can differ from 30 cm with the Tier 2 method. However, this will require consistency with the depth of the reference C stocks (SOC_{REF}) and stock change factors (i.e., F_{LU}, F_I, and F_{MG}) to ensure consistent application of methods for determining the impact of land use change on soil C stocks. Box 4.3a provides information and references that can be used as a starting point for developing Tier 2 factors for forest management as well as observations on related challenges.

It is *good practice* to focus on the factors that have the largest overall effect, taking into account the impact on forest SOC and the extent of affected forests. Management practices can be coarsely labeled as intensive (e.g., plantation forestry) or extensive (e.g., natural forest); these categories can also be redefined according to national circumstances. The development of stock change factors is likely to be based on intensive studies at experimental sites and sampling plots involving replicated, paired site comparisons (Johnson *et al.*, 2002; Olsson *et al.*, 1996; see also the reviews by Johnson and Curtis, 2001; and Hoover, 2003). In practice, it may not be possible to separate the effects of different forest types, management practices and disturbance regimes, in which case stock change factors should be combined into a single modifier. If a country has well-documented data for different forest types under different management regimes, it might be possible to derive soil organic C estimates directly without using reference C stocks and adjustment factors. However, a relationship to the reference C stocks must be established so that the impact of land-use change can be computed without artificial increases or decreases in the C stocks due to a lack of consistency in the methods across the various land-use categories (i.e., Forest Land, Cropland, Grassland, Settlements, and Other Land).

Inventories can also be improved by deriving country-specific reference C stocks (SOC_{REF}), compiled from published studies or surveys. Such values are typically obtained through the development and/or compilation of large soil profile databases (Siltanen *et al.*, 1997; Scott *et al.*, 2002; Batjes 2011; De Vos *et al.*, 2015). Additional guidance for deriving stock change factors and reference C stocks is provided in Section 2.3.3.1 (Chapter 2).

BOX 4.3A (NEW)
DEVELOPING TIER 2 STOCK CHANGE FACTORS FOR FOREST LAND

Although the scientific basis is not sufficient for deriving default stock change factors for forest land, country specific Tier 2 factors can be developed if there is adequate data available to represent national circumstances. Several meta-analyses and reviews provide analyses and references to support incorporation of country-specific data into a Tier 2 method with estimation of management effects and corresponding stock change factors (F_{MG}) for Forest Land Remaining Forest Land. Quantification of management effects becomes increasingly important in cases in which forests represent a significant sink or source or in which changes in management intensity or practices result in gains or losses compared to earlier practices. Increased removal of harvest residues or stumps for bioenergy is one example of changes in management intensity and practices. Most analyses have focused on the effects following harvests of different intensities (e.g., Johnson and Curtis, 2001; Achat *et al*., 2015a; James and Harrison, 2016; Zhou *et al*., 2013). Response ratios or effect sizes based on measurements of soil carbon stocks reflect all changes associated with a management action; thus, separate carbon stock factors for input of organic matter (F_I) cannot be derived from the existing data.

Most field experiments have been carried out in cool temperate regions, and meta-analyses or reviews on harvest effects can be found to support adaptation of Tier 2 methods for these regions (Nave *et al*., 2010; Thiffault *et al*., 2011; Clarke et al., 2015; Hume *et al*., 2017). When selecting harvesting experiments on which to base the calculation of stock change factors, several factors need to be considered: intensity of harvest, treatment of harvest residues and other site preparation practices, such as burning, time since the management action, and soil layers and sampling depths (Liao *et al*., 2010; Strömgren *et al*., 2013; Achat *et al*., 2015b; James and Harrison, 2016; Dean *et al.*, 2017; Hume *et al*., 2017). Tree species composition, i.e., conifers versus broad-leaved or mixed species, could also influence the management effect although the influence can be confounded by other factors (e.g. Hume *et al.*, 2017). The question of control conditions for evaluating the management action is of great importance because the control is often not a native reference condition, but rather another managed forest (Dean *et al*., 2017). This should be taken into account when estimating a stock change factor based on several field studies as well as the relationship to country-specific reference soil C stock.

Conclusions on the harvesting effects differ between meta-analyses, which could be partly due to differences in field experiment set-ups and the different data selection and weighting procedures. As an example, whole-tree harvests resulted in average 7.5percent smaller carbon stocks in mineral soil than the stocks measured 10–30 years after stem-only harvests (Achat *et al*., 2015a). However, no effect of whole-tree harvest was found in some other meta-analyses (Clarke *et al.*, 2015; Hume *et al*., 2017) or a positive effect was reported (James and Harrison, 2016). However, there was a tendency for smaller carbon stocks in forest floor after whole-tree harvesting compared to stem-only harvesting or pre-treatment conditions (Johnson and Curtis, 2001; Thiffault *et al*., 2011; Clarke *et al.*, 2015).

Considerable spatial variability increases the challenge to detect relatively small management effects in soil C stocks (Jandl *et al*., 2007). However, most studies include only the first one or two decades after the harvest, which may too short to reveal impact of forest management actions on soil carbon stock changes, especially in cool climate regions with long rotation periods (Clarke *et al*., 2015; Dean *et al*., 2017). Non-linearity in the responses has also been observed. For example, an increase in soil C stocks after an initial decrease has been observed for a group of studies on Spodosols from a cool and humid climate with longer monitoring periods, up to eight decades of typical rotation lengths (James and Harrison, 2016).

In addition to guidance in this Chapter 4.2.3.2 above, detailed guidance on estimation of country-specific stock change factors and reference C stocks in general is given in Chapter 2, in Section 2.3.3.1., including guidance on using models to derive carbon stock change factors.

Tier 3

Constant stock change rate factors *per se* are less likely to be estimated in favor of variable rates that more accurately capture land-use and management effects. See Section 2.3.3.1 (Chapter 2) for further discussion.

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.2.

4.2.3.3 CHOICE OF ACTIVITY DATA

Mineral soils

Tier 1

For the Tier 1 approach, it is assumed that forest soil C stocks do not change with management, and therefore it is not necessary to classify forest into various types, management classes or natural disturbance regimes. However, if using Approach 1 activity data (see Chapter 3), environmental data will be needed to classify the country into climate regions and soil types in order to apply the appropriate reference C stocks to Forest Land. A detailed description of the default climate classification scheme is given in Chapter 3, Annex 3A.5. If the information needed to classify climate types is not available from national databases, there are international sources of climate data such as United Nations Environmental Program. Data will also be needed to classify soils into the default categories provided in Chapter 3, and if national data are not available to map the soil types, international soils data provide a reasonable alternative, such as the FAO Soils Map of the World.

Tier 2

Activity data for the Tier 2 approach consist of the major forest types, management practices, disturbance regimes and the areas to which they apply. It is preferable for the data to be linked with the national forest inventory, where one exists, and/or with national soil and climate databases. Typical changes include conversion of unmanaged to managed forest; conversion of forest type (native forest into a new forest type, such as plantation of exotic species and vice versa); intensification of forest management activities, such as site preparation, tree planting, interval and intensity of thinning and rotation length changes; changes in harvesting practices (bole vs. whole-tree harvesting; amount of residues left on-site); and the frequency of disturbances (e.g., pest and disease outbreaks, flooding, fires, typhoon/cyclone/hurricane, snow damage). Data sources will vary according to a country's forest management system, but could include individual contractors or companies, statutory forest authorities, research institutions and agencies responsible for forest inventories. Data formats vary widely, and include, among others, activity reports, forest management inventories and remote sensing imagery.

In addition, Tier 2 methods should involve a finer stratification of environmental data than the Tier 1 approach, including climate regions and soil types, which would likely be based on national climate and soils data. If a finer classification scheme is utilized in a Tier 2 inventory, reference C stocks will also need to be derived for the more detailed set of climate regions and soil types, and the land management data will need to be stratified based on the country-specific classification.

Tier 3

For application of dynamic models and/or a direct measurement-based inventory in Tier 3, similar or more detailed data on the combinations of climate, soil, topographic and management data are needed, relative to the Tiers 1 and 2 methods, but the exact requirements will be dependent on the model or measurement design.

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.2.

4.2.3.4 CALCULATION STEPS FOR TIER 1

No refinement.

4.2.3.5 UNCERTAINTY ASSESSMENT

Three broad sources of uncertainty exists in soil C inventories: 1) uncertainties in land-use and management activity and environmental data; 2) uncertainties in reference soil C stocks if using Tier 1 or 2 approaches (mineral soils only); and 3) uncertainties in the stock change/emission factors for Tier 1 or 2 approaches, model structure/parameter error for Tier 3 model-based approaches, or measurement error/sampling variability associated with Tier 3 measurement-based inventories. In general, precision of an inventory is increased (i.e., smaller confidence ranges) with more sampling to estimate values for the three broad categories. In addition, reducing bias (i.e., improve accuracy) is more likely through the development of a higher Tier inventory that incorporates country-specific information.

For Tier 1, uncertainties are provided with the reference C stocks in the first footnote of Table 2.3 (Chapter 2), and emission factor uncertainties for organic soils are provided in Table 4.6, Section 4.5. For organic soils, see guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.2. Uncertainties in land-use and management data will need to be addressed by the inventory compiler, and then combined with uncertainties for the default factors and reference C stocks (mineral soils only) using an appropriate method, such as simple error propagation equations. Refer to Section 4.2.1.5 for uncertainty estimate for land area estimates. However, it is *good practice* for the inventory compiler to derive uncertainties from country-specific activity data instead of using a default level.

Default reference C stocks for mineral soils and emission factors for organic soils can have inherently high uncertainties, particularly bias, when applied to specific countries. Defaults represent globally averaged values of land-use and management impacts or reference C stocks that may vary from region-specific values (Powers *et al.*, 2004; Ogle *et al.*, 2006). Bias can be reduced by deriving country-specific factors using Tier 2 method or by developing a Tier 3 country-specific estimation system. The underlying basis for higher Tier approaches will be research in the country or neighbouring regions that address the effect of land use and management on soil C. In addition, it is *good practice* to further minimize bias by accounting for significant within-country differences in land-use and management impacts, such as variation among climate regions and/or soil types, even at the expense of reduced precision in the factor estimates (Ogle *et al.*, 2006). Bias is considered more problematic for reporting stock changes because it is not necessarily captured in the uncertainty range (i.e., the true stock change may be outside of the reported uncertainty range if there is significant bias in the factors).

Uncertainties in land-use activity statistics may be improved through a better national system, such as developing or extending a ground-based survey with additional sample locations and/or incorporating remote sensing to provide additional coverage. It is *good practice* to design a classification that captures the majority of land-use and management activity with a sufficient sample size to minimize uncertainty at the national scale.

For Tier 2 methods, country-specific information is incorporated into the inventory analysis for purposes of reducing bias. For example, Ogle *et al.* (2003) utilized country-specific data to construct probability distribution functions for US specific factors, activity data and reference C stocks for agricultural soils. It is *good practice* to evaluate dependencies among the factors, reference C stocks or land-use and management activity data. In particular, strong dependencies are common in land-use and management activity data because management practices tend to be correlated in time and space. Combining uncertainties in stock change/emission factors, reference C stocks and activity data can be done using methods such as simple error propagation equations or Monte-Carlo procedures.

Tier 3 models are more complex and simple error propagation equations may not be effective at quantifying the associated uncertainty in resulting estimates. Monte Carlo analyses are possible (Smith and Heath, 2001), but can be difficult to implement if the model has many parameters (some models can have several hundred parameters) because joint probability distribution functions must be constructed quantifying the variance as well as covariance among the parameters (see e.g. Peltoniemi *et al.*, 2006; Metsaranta *et al*., 2017). However, if soil model parameters have been estimated with a Bayesian approach, the resultant joint probability distribution for the parameters can be sampled in a Monte Carlo Analysis to capture parameter uncertainty, along with sampling of probability distribution functions for model inputs and other associated data, see Lehtonen and Heikkinen (2016). Other methods are also available such as empirically-based approaches (Monte *et al.*, 1996), which use measurements from a monitoring network to statistically evaluate the relationship between measured and modelled results (Falloon and Smith, 2003; Ogle *et al.*, 2007). In contrast to modelling, uncertainties in measurement-based Tier 3 inventories can be determined from the sample variance, measurement error and other relevant sources of uncertainty.

4.2.4 Non-CO_2 greenhouse gas emissions from biomass burning

No refinement.

4.3 LAND CONVERTED TO FOREST LAND

4.3.1 Biomass

No refinement.

4.3.2 Dead organic matter

No refinement.

4.3.3 Soil carbon

Land conversions on mineral soils generally either maintain similar levels of C storage or create conditions that increase soil C stocks, particularly if the land was previously managed for annual crop production (Post and Kwon, 2000). However, under certain circumstances, Grassland conversion to Forest Land has been shown to cause small C losses in mineral soils for several decades following conversion (Davis and Condron, 2002; Paul et al., 2002). Emissions of C from organic soils will vary depending on the previous use and level of drainage. Specifically, conversion from Cropland will tend to decrease emissions; conversions from Grassland will likely maintain similar emission rates; while conversion from Wetlands often increases C emissions.

General information and guidelines on estimating changes soil C stocks are found in Section 2.3.3 in Chapter 2 (including equations) and need to be read before proceeding with guidelines dealing with forest soil C stocks. The total change in soil C stocks for *Land Converted to Forest Land* is computed using Equation 2.24 (Chapter 2), which combines the change in soil organic C stocks for mineral soils and organic soils; and carbon stock changes for inorganic soil C pools (Tier 3 only). This section provides specific guidance for estimating soil organic C stock changes; see Section 2.3.3.1 (Chapter 2) for general discussion on soil inorganic C (no additional information is provided in the Forest Land discussion below).

To account for changes in soil C stocks associated with *Land Converted to Forest Land*, countries need to have, at a minimum, estimates of the areas of *Land Converted to Forest Land* during the inventory time period, stratified by climate region and soil type. If land-use and management data are limited, Approach 1 activity data can be used as a starting point, along with knowledge of country experts of the approximate distribution of land-use types being converted. If previous lands uses and conversions for *Land Converted to Forest Land* are unknown, SOC stocks changes can still be computed using the methods provided in *Forest Land Remaining Forest Land*, but the land base will likely be different for forests in the current year relative to the initial year in the inventory. It is critical, however, that the total land area across all land-use sectors be equal over the inventory time period (e.g., if 5 Million ha is converted from Cropland and Grassland to Forest Land during the inventory time period, then Forest Land will have an additional 5 Million ha in the last year of the inventory, while Cropland and Grassland will have a corresponding loss of 5 Million ha in the last year), and the total change will be estimated when summing SOC stocks across all land uses. *Land Converted to Forest Land* is stratified according to climate regions and major soil types, which could either be based on default or country-specific classifications. This can be accomplished with overlays of climate and soil maps, coupled with spatially-explicit data on the location of land conversions.

Inventories can be developed using Tier 1, 2 or 3 approaches, with each successive Tier requiring more detail and resources than the previous. It is possible that countries will use different tiers to prepare estimates for the separate components in this source category (i.e., soil organic C stocks changes in mineral soils and organic soils; and stock changes associated with soil inorganic C pools).

4.3.3.1 CHOICE OF METHOD

Inventories can be developed using Tier 1, 2 or 3 approaches and countries may choose different tiers for mineral and organic soils. Decision trees are provided for mineral (Figure 2.4) and organic soils (Figure 2.5) in Section 2.3.3.1 (Chapter 2) to assist inventory compilers with selection of the appropriate tier for their soil C inventory.

Mineral soils

Tier 1

Change in soil organic C stocks can be estimated for mineral soils with land-use conversion to Forest Land using Equation 2.25 (Chapter 2). For Tier 1, the initial (pre-conversion) soil organic C stock ($SOC_{(0-T)}$) and C stock in the last year of the inventory time period (SOC_0) are determined from the common set of reference soil organic C stocks (SOC_{REF}) and default stock change factors (F_{LU}, F_{MG}, F_I) as appropriate for describing land use and management both pre- and post-conversion. Note that area of exposed bedrock in Forest Land or the previous land use are not included in the soil C stock calculation (assume a stock of 0). Annual rates of stock changes are calculated as the difference in stocks (over time) divided by the time dependence (D) of the stock change factors (default is 20 years).

Tier 2

The Tier 2 approach for mineral soils also uses Equation 2.25 (Chapter 2), but involves country or region-specific reference C stocks and/or stock change factors and possibly more disaggregated land-use activity and environmental data.

Tier 3

Tier 3 approaches will involve more detailed and country-specific models and/or measurement-based approaches along with highly disaggregated land-use and management data. It is *good practice* that Tier 3 approaches estimating soil C change from land-use conversions to Forest Land, employ models, monitoring networks and/or data sets that are capable of representing transitions over time from other land uses, including Grassland, Cropland and possibly Settlements or other land uses. It is important that models be evaluated with independent observations from country or region-specific field locations that are representative of the interactions of climate, soil and forest type/management on post-conversion change in soil C stocks.

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.3.

4.3.3.2 CHOICE OF STOCK CHANGE AND EMISSION FACTORS

Mineral soils

Tier 1

For native unmanaged land, as well as for managed Forest Land, Settlements and nominally managed Grassland with low disturbance regimes, soil C stocks are assumed equal to the reference values (i.e., land use, disturbance (forests only), management and input factors equal 1), but it will be necessary to apply the appropriate stock change factors to represent other systems which may be converted to Forest Land, such as improved and degraded Grassland, as well as all Cropland systems. See the appropriate land-use section for default stock change factors (Forest Land in 4.2.3.2, Cropland in Section 5.2.3.2, Grassland in 6.2.3.2, Settlements in 8.2.3.2, and Other Land in 9.3.3.2). Default reference C stocks are found in Table 2.3 (Chapter 2).

Tier 2

Estimation of country-specific stock change factors is probably the most important development associated with the Tier 2 approach. Differences in soil organic C stocks among land uses are computed relative to a reference condition. If default reference C stocks are used, the reference condition is native vegetation that is neither degraded nor improved through land-use and management practices. Stock change factors for land-use conversion to native forests will be equal to 1 if the forest represents the reference condition. However, stock change factors will need to be derived for *Land Converted to Forest Land* that do not represent the reference condition, accounting for the influence of disturbance (F_D), input (F_I) and management (F_{MG}), which are then used to further refine the C stocks of the new forest system. See the appropriate section for specific information regarding the derivation of stock change factors for other land-use sectors (Cropland in 5.2.3.2, Grassland in Section 6.2.3.2, Settlements in 8.2.3.2, and Other Land in 9.3.3.2).

Reference C stocks can also be derived from country-specific data in a Tier 2 approach. Reference values in Tier 1 correspond to non-degraded, unimproved lands under native vegetation, but other reference conditions can also be chosen for Tier 2. In general, reference C stocks should be consistent across the land uses (i.e., Forest Land, Cropland, Grassland, Wetlands, Settlements, Other Land) (see section 2.3.3.1). Therefore, the same reference stock should be used for each climate zone and soil type, regardless of the land use. The reference stock is then multiplied by land use, input and management factors to estimate the stock for each land use based on the set of management systems that are present in a country. In addition, the depth for evaluating soil C stock changes can be different with the Tier 2 method. However, this will require consistency with the depth of the reference C stocks (SOC_{REF}) and stock change factors for all land uses (i.e., F_{LU}, F_I, and F_{MG}) to ensure consistency in the application of methods for estimating the impact of land use change on soil carbon stocks. Additional guidance is provided in Chapter 2, Section 2.3.3.1.

The carbon stock estimates may be improved when deriving country-specific factors for F_{LU} and F_{MG}, by expressing carbon stocks on a soil-mass equivalent basis rather than a soil-volume equivalent (i.e., fixed depth) basis. This is because the soil mass in a certain soil depth changes with the various operations associated with land use that affect the density of the soil, such as uprooting, land levelling, tillage, and rain compaction due to the disappearance of the cover of tree canopy. However, it is important to realize that all data used to derive stock change factors across all land uses must be on an equivalent mass basis if this method is applied. This will be challenging to do comprehensively for all land uses. See Box 2.2c in Chapter 2, Section 2.3.3.1 for more information.

Tier 3

Constant stock change rate factors *per se* are less likely to be estimated in favor of variable rates that more accurately capture land-use and management effects. See Section 2.3.3.1 (Chapter 2) for further discussion.

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.3.

4.3.3.3 CHOICE OF ACTIVITY DATA

Mineral soils

Tier 1 and Tier 2

For purposes of estimating soil carbon stock change, area estimates of *Land Converted to Forest Land* should be stratified according to major climate regions and soil types. This can be based on overlays with suitable climate and soil maps and spatially-explicit data of the location of land conversions. Detailed descriptions of the default climate and soil classification schemes are provided in Chapter 3. Specific information is provided in the each of the land-use sections regarding treatment of land-use/management activity data (Forest Land in Section 4.2.3.3, Cropland in 5.2.3.3, Grassland in 6.2.3.3, Wetlands in 7.2.3.2, Settlements in 8.2.3.3, and Other Land in 9.3.3.3).

One critical issue in evaluating the impact of Land Converted to Forest Land on soil organic C stocks is the previous land-use and management activity. Activity data gathered using Approach 2 or 3 (see Chapter 3 for discussion about Approaches) provide the underlying basis for determining the previous land use and management for Land Converted to Forest Land. In contrast, aggregate data (Approach 1, Chapter 3) only provide the total amount of area in each land use and do not form a basis for determining specific transitions. Moreover, aggregate data only represent the net changes in land use and management rather than the gross changes, which could be considerably larger and may have an impact on the total soil C stock changes. Regardless, with aggregate data (Approach 1), changes in soil organic C stocks may be computed separately for each land-use category and then combined to obtain the total stock change even if the total changes do not capture the full dynamics occurring with land use change. Using this approach, it will be necessary for coordination among each land-use category to ensure the total land base is remaining constant over time, given that some land area will be lost and gained within individual land-use category during each inventory year due to land-use change. Further clarification on soil organic C estimation methods in case of land-use change is presented in Section 2.3.3.1.

Tier 3

For application of dynamic models and/or a direct measurement-based inventory in Tier 3, similar or more detailed data on the combinations of climate, soil, topographic and management data are needed, relative to Tier 1 or 2 method, but the exact requirements will be dependent on the model or measurement design.

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.3.

4.3.3.4 CALCULATION STEPS FOR TIER 1

Mineral soils

The steps for estimating SOC_0 and $SOC_{(0-T)}$ and net soil C stock change per ha of *Land Converted to Forest Land* are as follows:

Step 1: Determine the land-use and management by mineral soil types and climate regions for land at the beginning of the inventory period, which can vary depending on the time step of the activity data (0-T; e.g., 5, 10 or 20 years ago).

Step 2: Select the native reference C stock value (SOC_{REF}), based on climate and soil type from Table 2.3, for each area of land being inventoried. The reference C stocks are the same for all land-use categories to ensure that erroneous changes in the C stocks are not computed due to differences in reference stock values among sectors.

Step 3: Select the land-use factor (F_{LU}), management factor (F_{MG}) and C input levels (F_I) representing the land-use and management system present before conversion to forest. Values for F_{LU}, F_{MG} and F_I are given in the respective section for the land-use sector (Cropland in Chapter 5, and Grassland in Chapter 6).

Step 4: Multiply these values by the reference soil C stock to estimate of 'initial' soil organic C stock ($SOC_{(0-T)}$) for the inventory time period.

Step 5: Estimate SOC_0 by repeating step 1 to 4 using the same native reference C stock (SOC_{REF}), but with land-use, management and input factors that represent conditions in the last (year 0) inventory year. For Tier 1, all stock change factors are assumed equal to 1 for Forest Land (although for Tier 2, different values for these factors under newly converted Forest Land should be used, based on country-specific data).

Step 6: Estimate the average annual change in soil C stock for the area over the inventory time period, $\Delta C_{CC_{Mineral}}$, (see Equation 2.25 in Chapter 2).

Step 7: Repeat Steps 1 to 6 if there are additional inventory time periods (e.g., 1990 to 2000, 2001 to 2010, etc.).

A numerical example is given below for afforestation of cropland soil.

Example: An area of 100,000 ha of cropland was planted to forest. The soil type is an Ultisol in a tropical moist climate, which has a native reference stock, SOC_{Ref} (0-30 cm), of 47 tonnes C ha^{-1} (Table 2.3). The previous land use was annual row crops, with conventional tillage, no fertilization and where crop residues are removed, so that the soil carbon stock at the beginning of the inventory time period (in this example, 5 yrs earlier in 1995) was ($SOC_{Ref} \bullet F_{LU} \bullet F_{MG} \bullet F_I$) = 47 tonnes C $ha^{-1} \bullet 0.48 \bullet 1 \bullet 0.92$ = 20.8 tonnes C ha^{-1} (see Table 5.5, Chapter 5, for stock change factor for cropland). Under Tier 1, managed forest is assumed to have the same soil C stock as the reference condition (i.e. all stock change factors are equal to 1). Thus, the average annual change in soil C stock for the area over the inventory time period is estimated as (47 tonnes C ha^{-1} – 20.8 tonnes C ha^{-1}) / 20 yrs = 1.3 tonnes C ha^{-1} yr^{-1}. For the area reforested there is an increase of 131,000 tonnes C yr^{-1}. (Note: 20 years is the time dependence of the stock change factor, i.e., factor represents annual rate of change over 20 years)

Organic soils

No refinement.

See guidance in *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Chapter 2, Section 2.3.

4.3.3.5 UNCERTAINTY ASSESSMENT

No refinement.

4.4 COMPLETENESS, TIME SERIES, QA/QC, AND REPORTING AND DOCUMENTATION

4.4.1 Completeness

No refinement.

4.4.2 Developing a consistent time series

It is *good practice* to develop a consistent time series of inventories of anthropogenic emissions and removals of greenhouse gases for all AFOLU categories using the guidance in Volume 1, Chapter 5. Because forest-related activity data and emission factors may only be available every few years, achieving time series consistency may require interpolation or extrapolation from longer timeseries or trend.

In addition to the general guidance on gap filling (e.g. on linear interpolation or extrapolation) in Volume 1, Chapter 5, further guidance is provided here on how to ensure methodological consistency in the case of the Forest Land category. When extrapolation may allow reflecting the evolution of the main drivers of emissions and removals during the period to be gap filled, including forest increment and harvest, with a greater level of accuracy than a linear interpolation or extrapolation.

Generally, these functional relationships are expressed in models which are applied to simulate the dynamics of carbon stocks in different pools, taking into account a number of interrelated variables.These variables include: forest characteristics (i.e. forest types, soil types, tree species composition, growing stock, age-class structure) and management practices (i.e. regeneration modality, rotation lengths, thinning frequency, etc.); the carbon pools and gases; the estimation parameters for HWP; the treatment of natural disturbances; the possible inclusion of impact of "indirect human-induced effects" (see Section 2.5), such as human-induced climate and environmental changes (e.g., temperature, precipitation, CO_2 and nitrogen deposition feedbacks) that affect growth, mortality, decomposition rates and natural disturbances regimes.

Among these, harvest volume is a key driver of emissions and removals. To this regard, if the actual harvest volume for the period to be extrapolated is known with confidence, then the model may directly apply this harvest volume, in combination with the other variables above. However, sometimes no reliable statistics on harvest volume (or other suitable proxies) are available for the period to be gap-filled. In this case, it is *good practice* to assume that the historical management practices continue during the period to be gap-filled. These practices should be those applied (and documented) in the existing time series, e.g. for the "calibration period" (see below). The functional relationships between available timber stocks, age structure dynamics, the increment and the harvest volume under the continuation of management practices (which is the basis of yield tables for forest management) can be used to calculate a consistent time series of annual C stock gains (forest net increment) and annual C stock losses (e.g. harvest, etc.). For example, if a given tree species is typically harvested at 80 years, the extrapolation based on functional relationships will apply this harvesting age (i.e. the historical forest management practice) also in the period to be gap-filled, taking into account the age structure dynamics (e.g. if the forest is getting older, more area reaching 80 years may be available); the carbon gains will be calculated using the forest net increment associated with the age structure and harvest volume simulated for the period to be gap-filled. An example of resolving data gaps in Forest Land through an extrapolation based on functional relationships is provided in Box 4.3b.

It is *good practice* that the model used for extrapolation utilizes information on the methodological elements above that is consistent with those used in the rest of the time series.

A change in any of the variables above used in the existing (non-extrapolated) time series (e.g., adding a new carbon pool) triggers a methodological inconsistency, to be addressed through a re-run, for the entire time series, of the model used for the extrapolation. Such re-run should ensure consistency in the variables described above.

As a general check for the consistency, it is *good practice* to demonstrate that the model used for the extrapolation reproduces the existing time series, for a selected "calibration period". The length of this calibration period may depend on various factors, but it is preferable to have at least 5 or 10 years of comparison between the model's results and the existing time series. If the model results for the calibration period fall within the estimated range of uncertainty of the existing time series (as documented in the GHG inventory), any remaining discontinuity between the existing time series and the portion extrapolated may be addressed through the application of the "overlap" technique (Volume 1, Chapter 5.3.3.1) to extrapolated data. This procedure will affect the level of modelled GHG estimates, but not their trend. If, for the calibration period, the model's results do not fall within the reported range of uncertainty of the existing time series, it is *not good practice* to use these results for extrapolating the time series. An example of resolving forest data gaps through extrapolation based on functional relationships is provided in Box 4.3b

BOX 4.3B (NEW)
EXAMPLE OF RESOLVING FOREST DATA GAPS THROUGH EXTRAPOLATION BASED ON FUNCTIONAL RELATIONSHIPS

Consider a case in which the stock difference method (see Volume 4, Chapter 2.3) is applied to construct a consistent time series between 1990 and 2015. Suppose that the next complete forest inventory will be reported in 2025, and that no reliable harvest data after 2015 is available. Until this inventory becomes available, the GHG emissions after 2015 may need to be extrapolated.

One option is to apply a linear extrapolation to the historical time series. Another option, to be considered especially when age structure dynamics exert a relevant impact on the trend of forest CO_2 fluxes, is to extrapolate the historical GHG emissions through functional relationships. To this aim, a model may be used to calculate, for the period to be gap-filled, the net increment and the harvest volumes associated with the continuation of historical management practices.

A theoretical example of the impact of different extrapolation approaches is provided in the following table, for selected years and for the living biomass of forests that are assumed to approach maturity.

For the purpose of extrapolating based on functional relationships, a model calculates the harvest volumes in the period to be gap-filled through the intersection between the continuation of historical forest management practices and the available timber stocks as affected by the age-related forest dynamics.

Historical period			**Linear extrapolation**	**Extrapolation based on functional relationships**
(ktC yr-1)	**2000**	**2015**	**2020**	**2020**
Net increment	20.0	26.0	28.0	26.0
Harvest	14.0	17.0	18.0	22.0
Net change	6.0	9.0	10.0	4.0

In this example, the net forest increment has increased in the historical period (2000-2015) more than the increase in harvest volumes. As a result, the sink (net change in C) has also increased. A linear extrapolation of this trend would lead to a further increase on the sink in 2020. However, in this example, the forests are aging, i.e. more forest area reaches maturity. As a consequence, assuming the continuation of the historical forest management practices, in 2020 the net increment is expected to saturate (i.e. in the table it remains at the 2015 levels) and the total harvest volume is expected to increase (because more area will reach maturity, and thus more biomass will be ready to be harvested). The resulting sink would also decline, in contrast with what obtained by the linear extrapolation. In this theoretical case, the extrapolation based on functional relationships may be considered to provide a more realistic estimate of GHG emissions in the period to be gap-filled.

Where countries use Tier 1 methods, estimates of dead organic matter (DOM) stock changes are only provided in the case of land-use change to or from Forest Land. It is *good practice* to recalculate the entire time series of data if either the default values for litter and dead wood carbon pools or the lengths of the transition periods are changed. It is also *good practice* to recalculate the entire time series of estimates if revisions to activity data, such as the rate of land-use change, have occurred. As more ground plot and other sample data on dead wood and litter carbon stocks become available in the future, countries are likely to improve the models used in higher Tier estimation procedures. It is *good practice* to use the same model parameter values (such as litterfall rates, decay rates, disturbance impacts) for the entire time series and to recalculate the entire time series if one or more of the model parameters have changed. Failure to do so may result in artificial sources or sinks, for example as a result of decay rate modifications.

4.4.3 Quantity Assurance and Quality Control

No refinement.

4.4.4 Reporting and Documentation

No refinement.

4.5 TABLES

Table 4.1

No refinement.

Table 4.2

No refinement.

Table 4.3

No refinement.

TABLE 4.4 (UPDATED)
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R) [TONNE ROOT D.M. (TONNE SHOOT D.M.)$^{-1}$]

Domain	Ecological zone[1]	Continent	Origin (Natural/Plantation)	Above-ground biomass (tonnes ha^{-1})	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	Uncertainty	Uncertainty type	References
Tropical	Tropical Rainforest	Africa	Natural	≤ 125	0.825	±90%	default	1, 2
			Natural	> 125	0.532	±90%	default	2, 3
		North and South America	Natural	≤ 125	0.221	0.036	SD	4
			Planted	≤ 125	0.170	0.11	SD	5
			Natural	> 125	0.221	0.036	SD	4
			Planted	> 125	0.170	0.11	SD	5
		Asia	Natural	≤ 125	0.207	0.072	SD	6, 7, 8
			Planted	≤ 125	0.325	0.025	SD	8
			Natural	> 125	0.212	0.077	SD	7, 8, 9, 10, 11
	Tropical Moist	Africa	Natural	≤ 125	0.232	±90%	default	12
			Natural	> 125	0.232	±90%	default	12
		North and South America	Natural	≤ 125	0.2845	0.061	SD	12
			Natural	> 125	0.284	0.061	SD	12
		Asia	Natural	≤ 125	0.323	0.073	SD	1, 13, 14, 5
			Natural	> 125	0.246	0.036	SD	12, 16
	Tropical Dry	Africa	Natural	≤ 125	0.332	0.247	SD	1, 12, 17, 18, 19
			Natural	> 125	0.379	0.040	SD	12
		North and South America	Natural	≤ 125	0.334	0.040	SD	4, 12, 20
			Natural	> 125	0.379	0.040	SD	12
		Asia	Natural	≤ 125	0.440	±90%	default	12
			Natural	> 125	0.379	0.040	SD	12
	Tropical Mountain	North and South America	Natural	≤ 125	0.348	±90%	default	4
			Planted	≤ 125	2.158	±90%	default	12
			Natural	> 125	0.283	0.16	SD	21
		Asia	Natural	≤ 125	0.322	0.084	SD	22, 23
			Natural	> 125	0.345	0.280	SD	22, 23

TABLE 4.4 (UPDATED) (CONTINUED)
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R) [TONNE ROOT D.M. (TONNE SHOOT D.M.)$^{-1}$]

Domain	Ecological zone[1]	Continent	Origin (Natural/ Plantation)	Above-ground biomass (tonnes ha^{-1})	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	Uncertainty	Uncertainty type	References
Sub-tropical	Sub-tropical Humid	Africa	Natural	≤ 125	0.232	±90%	default	12
			Natural	> 125	0.232	±90%	default	12
		North and South America	Natural	≤ 125	0.175	±90%	default	12
			Natural	> 125	0.284	±90%	default	12
		Asia	Natural	≤ 125	0.230	±90%	default	12
			Natural	> 125	0.246	±90%	default	12
	Sub-tropical Dry	North and South America	Natural	≤ 125	0.336	±90%	default	12
			Natural	> 125	0.352	0.047	SD	12
		Asia	Natural	≤ 125	0.440	0.184	SD	12
			Natural	> 125	0.440	0.184	SD	12
	Sub-tropical Steppe	North and South America	Natural	≤ 125	1.338	±90%	default	12
		Asia	Natural	> 125	1.338	±90%	default	12
			Planted	≤ 125	2.158	±90%	default	12
Temperate	Oceanic	Europe	Natural/Planted (Other Broadleaf)	all size classes	0.192	±90%	default	24
			Natural (Conifer)	≤ 125	0.359	±90%	default	12
			Natural (Other Broadleaf)	>125	0.172	±90%	default	12
			Planted (Conifer)	>125	0.206	±90%	default	12, 25, 26, 27
			Planted (Conifer)	all size classes	0.359	0.145	SD	28
			Planted (Quercus)	≤ 125	1.400	±90%	default	29
		North and South America	Natural (Conifer)	≤ 125	0.337	±90%	default	12
			Natural (Conifer)	>125	0.338	±90%	default	12
			Natural (Other Broadleaf)	≤ 125	0.466	±90%	default	12, 30
			Natural (Other Broadleaf)	>125	0.190	±90%	default	12, 31
			Planted (Conifer)	>125	0.203	±90%	default	12, 32

TABLE. 4.4 (UPDATED) (CONTINUED)
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R) [TONNE ROOT D.M. (TONNE SHOOT D.M.)$^{-1}$]

Domain	Ecological zone[1]	Continent	Origin (Natural/Plantation)	Above-ground biomass (tonnes ha^{-1})	R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]	Uncertainty	Uncertainty type	References
Temperate	Oceanic	Oceania	Natural (Eucalyptus)	≤ 125	0.464	±90%	default	12
			Natural (Eucalyptus)	>125	0.257	±90%	default	12
			Natural (Other Broadleaf)	≤ 125	0.213	±90%	default	34-36
			Natural (Other Broadleaf)	>125	0.313	±90%	default	37, 38
			Planted (Conifer)	all size classes	0.190	±90%	default	39
			Planted (Conifer)	≤ 125	0.634	±90%	default	12
			Planted (Conifer)	>125	0.294	±90%	default	12
			Planted (Eucalyptus)	≤ 125	0.391	±90%	default	12
			Natural (Eucalyptus)	>125	0.188	±90%	default	12, 40
	Continental	Europe	Natural (Quercus)	>125	0.477	±90%	default	12
			Planted (Conifer)	≤ 125	0.340	±90%	default	12
		North and South America	Natural (Other Broadleaf)	≤ 125	0.481	±90%	default	12
			Natural (Other Broadleaf)	>125	0.277	±90%	default	12
			Planted (Conifer)	≤ 125	0.237	±90%	default	12
	Oceanic Continental Mountain	Asia	Natural (Conifer)	≤ 125	0.243	±90%	default	33
			Natural (Conifer)	>125	0.262	±90%	default	33
			Natural (Other Broadleaf)	≤ 125	0.225	±90%	default	33
			Natural (Other Broadleaf)	>125	0.229	±90%	default	33

<table>
<tr><th colspan="9">TABLE. 4.4 (UPDATED) (CONTINUED)
RATIO OF BELOW-GROUND BIOMASS TO ABOVE-GROUND BIOMASS (R) [TONNE ROOT D.M. (TONNE SHOOT D.M.)$^{-1}$]</th></tr>
<tr><th>Domain</th><th>Ecological zone[1]</th><th>Continent</th><th>Origin (Natural/Plantation)</th><th>Above-ground biomass (tonnes ha^{-1})</th><th>R [tonne root d.m. (tonne shoot d.m.)$^{-1}$]</th><th>Uncertainty</th><th>Uncertainty type</th><th>References</th></tr>
<tr><td rowspan="4">Temperate</td><td rowspan="4">Oceanic Continental Mountain</td><td rowspan="4">Asia</td><td>Planted (Conifer)</td><td>≤ 125</td><td>0.224</td><td>±90%</td><td>default</td><td>33</td></tr>
<tr><td>Planted (Conifer)</td><td>>125</td><td>0.232</td><td>±90%</td><td>default</td><td>33</td></tr>
<tr><td>Planted (other Broadleaf)</td><td>≤ 125</td><td>0.307</td><td>±90%</td><td>default</td><td>33</td></tr>
<tr><td>Planted (other Broadleaf)</td><td>>125</td><td>0.248</td><td>±90%</td><td>default</td><td>33</td></tr>
<tr><td rowspan="2">Boreal</td><td rowspan="2">Coniferous, tundra woodland, mountain systems</td><td rowspan="2">-</td><td rowspan="2">-</td><td>≤ 75</td><td>0.390</td><td>0.23 - 0.96</td><td>Range</td><td>12, 46</td></tr>
<tr><td>>75</td><td>0.240</td><td>0.15 - 0.37</td><td>Range</td><td>12, 46</td></tr>
<tr><td colspan="9">[1] Forest Resources Assessment (FRA). (2015). Global Eological Zones for FAO Forest Reporting 2010 Update. Forest Resources Assessment Working Paper 179.
References:
1Masota, A.M., et al., 2016; 2Njana, M.A., et al., 2015; 3Masota, A.M., et al., 2015; 4FAO, 2015; 5Sanquetta, et al., 2011; 6Saner, P., et al., 2012; 7Murdiyarso, M., et al., 2015; 8Kotowska, M.M., et al., 2015; 9Lu, X.T., et al., 2010; 10Niiyama K, et al., 2010; 11Krisnawati, H., et al., 2014; 12Mokany, K., et al., 2006; 13Wang, X.P., et al., 2008; 14Li, X., et al., 2010; 15Monda, Y., et al., 2016; 16Gautum, T.P., Mandal, T.N., 2016; 17Mugasha, W.A., et al., 2013; 18Malimbwi, R.E., et al., 2016; 19Makero, et al., 2016; 20Sato, T., et al., 2015; 21Moser, G., 2011; 22Iqbal, K., et al., 2014; 23Sharma, D.P., 2009; 24Skovsgaard, J.P., Nord-Larsen, T., 2012; 25Green C., et al., 2007; 26Urban, J., et al., 2015; 27Xiao, C.W., et al., 2003; 28Levy, P.E., et al., 2004; 29Cotillas, M., et al., 2016; 30Gargaglione, et al., 2010; 31Frangi, J.L., et al., 2005; 32Miller, A.T., et al., 2006; 33Luo, Y., et al., 2014; 34Schwendenmann, L., Mitchell, N., 2014; 35Watson, A,. O'Loughlin, C., 1985; 36Watson, A., 1995; 37Beets, P.N., 1980; 38Miller, R. B. 1963; 39Beets PN, et al. 2007; 40Oliver GR, et al. 2009; 41Battles, J. J., et al. 2002; 42Laclau P. 2003; 43Grimm, U., Fassbender, H., 1981, 44Edwards, P., Grubb, P., 1977; 45Scott, N.A., et al., 2005; 46Li, et al., 2003.</td></tr>
</table>

Table 4.5

No refinement.

Table 4.6

No refinement.

TABLE 4.7 (UPDATED) ABOVE-GROUND BIOMASS IN NATURAL FORESTS (TONNES D.M. HA^{-1})							
Domain	**Ecological zone [1]**	**Continent**	**Status/condition[2]**	**Above-ground biomass [tonnes d.m. ha^{-1}]**	**Uncertainty**	**Uncertainty type**	**References**
Tropical	Tropical rainforest	Africa	Primary	404.2	120.4	SD	1-12
			Secondary >20 years	212.9	143.1	SD	5-7, 11, 13-16
			Secondary ≤20 years	52.8	35.6	SD	9-11, 14, 15, 17
		North and South America	Primary	307.1	104.9	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	206.4	80.4	SD	9, 10, 22-28
			Secondary ≤20 years	75.7	34.5	SD	9, 10, 14, 22, 23, 28-32
		Asia	Primary	413.1	128.5	SD	3, 4, 9, 10, 33-35
			Secondary >20 years	131.6	20.7	SD	9, 10, 36, 37
			Secondary ≤20 years	45.6	20.6	SD	9, 10, 37-39
	Tropical moist deciduous forest	Africa	Primary	236.6	104.7	SD	1, 2, 16
			Secondary >20 years Secondary ≤20 years	72.8	36.4	SD	9, 10, 16, 40-47
		North and South America	Primary	187.3	94.0	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	131.0	54.2	SD	9, 10, 22-26
			Secondary ≤20 years	55.7	28.7	SD	9, 10, 22, 23, 25, 26
		Asia	Primary Secondary >20 years Secondary ≤20 years	67.7	93.4	SD	9, 10, 35, 48-50
	Tropical dry forest	Africa	Primary Secondary >20 years Secondary ≤20 years	69.6	47.5	SD	1, 2, 43, 44, 51-53
		North and South America	Primary	127.5	72.6	SD	18-21
			Secondary >20 years	118.9	81.3	SD	9, 10, 22, 23, 54
			Secondary ≤20 years	32.2	24.2	SD	9, 10, 22, 23, 54, 55
		Asia	Primary Secondary >20 years Secondary ≤20 years	184.6	144.5	SD	9, 10, 35, 48, 56
	Tropical shrublands	Africa	Primary Secondary >20 years Secondary ≤20 years	48.4	45.8	SD	44, 57, 58
		North and South America	Primary Secondary >20 years Secondary ≤20 years	71.5	46.4	SD	59
		Asia	Primary Secondary >20 years Secondary ≤20 years	38.3	33.0	SD	59

Table 4.7 (Updated) (Continued) Above-ground biomass in natural forests (tonnes d.m. ha⁻¹)							
Domain	**Ecological zone [1]**	**Continent**	**Status/condition[2]**	**Above-ground biomass [tonnes d.m. ha^{-1}]**	**Uncertainty**	**Uncertainty type**	**References**
Tropical	Tropical mountain systems	Africa	Primary	190.0	131.2	SD	1-4, 9, 10, 42-44, 47, 53, 60-68
			Secondary >20 years				
			Secondary ≤20 years				
		North and South America	Primary	195.0	95.6	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	184.4	111.0	SD	9, 10, 22, 23, 26, 69
			Secondary ≤20 years	75.9	51.1	SD	9, 10, 22, 23, 26, 69, 70
		Asia	Primary	433.5	147.5	SD	3, 4, 9, 10, 34, 35
			Secondary >20 years	66.4	61.0	SD	9, 10, 50, 71-73
			Secondary ≤20 years				
Sub-tropical	Sub-tropical humid forests	Africa	Primary	54.1	20.6	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		North and South America	Primary	84.5	42.9	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		Asia	Primary	323.0	157.7	SD	9, 10
			Secondary >20 years	258.4	128.1	SD	9, 10
			Secondary ≤20 years				
	Sub-tropical dry forests	Africa	Primary	65.2	27.1	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		North and South America	Primary	115.9	46.2	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		Asia	Primary	70.9	26.2	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
	Sub-tropical steppe	Africa	Primary	50.5	23.9	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		North and South America	Primary	44.0	26.0	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		Asia	Primary	41.6	24.7	SD	59
			Secondary >20 years				
			Secondary ≤20 years				

TABLE 4.7 (UPDATED) (CONTINUED)
ABOVE-GROUND BIOMASS IN NATURAL FORESTS (TONNES D.M. HA^{-1})

Domain	Ecological zone [1]	Continent	Status/condition[2]	Above-ground biomass [tonnes d.m. ha^{-1}]	Uncertainty	Uncertainty type	References
Sub-tropical	Sub-tropical mountain systems	Africa	Primary	35.1	22.2	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		North and South America	Primary	74.6	40.1	SD	59
			Secondary >20 years				
			Secondary ≤20 years				
		Asia	Primary	250.2	59.4	SD	9, 10
			Secondary >20 years	155.2	41.7	SD	9, 10
			Secondary ≤20 years				
Temperate	Mountain	Asia	Primary	n.a	n.a	n.a	
			Secondary >20 years	170.4	±57.85	95% CI	75
			Secondary ≤20 years	n.a	n.a	n.a	
		Europe	Primary	301.1	±90%	default	76-79
			Secondary >20 years	214.7	±90%	default	77
			Secondary ≤20 years	27.8	±90%	default	77
		North and South America	Primary	n.a	n.a	n.a	
			Secondary >20 years	185.9	153.8	SD	80
			Secondary ≤20 years	57.9	78.6	SD	80
	Continental	Asia	Primary	n.a	n.a	n.a	
			Secondary >20 years	116.0	±18.37	95% CI	75
			Secondary ≤20 years	90.9	±40.43	95% CI	75
		Europe	Primary	332.4	±90%	default	77-79
			Secondary >20 years	162.0	±90%	default	77, 81-83
			Secondary ≤20 years	51.6	±90%	default	77, 81-83
		North and South America	Primary	n.a	n.a	n.a	
			Secondary >20 years	128.9	240.3	SD	80
			Secondary ≤20 years	46.0	99.5	SD	80
	Oceanic	Asia	Primary	289.8	±90%	default	84
			Secondary >20 years	n.a	n.a	n.a	
			Secondary ≤20 years				
		Europe	Primary	126.1	±90%	default	77
			Secondary >20 years	153.9	±90%	default	77,85-90
			Secondary ≤20 years	22.3	±90%	default	77
		Oceania	Primary	352.7	±17	95%CI	91
			Secondary >20 years	120.5	±22.3	95%CI	91
			Secondary ≤20 years	57.5	±14.28	95%CI	92

TABLE 4.7 (UPDATED) (CONTINUED)
ABOVE-GROUND BIOMASS IN NATURAL FORESTS (TONNES D.M. HA^{-1})

Domain	Ecological zone [1]	Continent	Status/condition[2]	Aboveground biomass [tonnes d.m. ha^{-1}]	Uncertainty	Uncertainty type	References
Temperate	Oceanic	North and South America	Primary	n.a	n.a	n.a	
			Secondary >20 years	354.1	455.7	SD	80
			Secondary ≤20 years	213.9	227.1	SD	80
	Desert	North and South America	Primary	n.a	n.a	n.a	
			Secondary >20 years	44.0	39.7	SD	80
			Secondary ≤20 years	25.6	35.1	SD	80
	Steppe	North and South America	Primary	n.a	n.a	n.a	
			Secondary >20 years	118.5	459.9	SD	80
			Secondary ≤20 years	42.9	76.5	SD	80
Boreal	Coniferous	North and South America	Primary	62.9	28.1	SD	93
			Secondary >20 years	n.a	n.a	n.a	
			Secondary ≤20 years	n.a	n.a	n.a	
	Tundra woodland	North and South America	Primary	63.7	30.1	SD	93
			Secondary >20 years	104.2	±90%	default	94
			Secondary ≤20 years	n.a	n.a	n.a	
	Mountain	North and South America	Primary	n.a	n.a	n.a	
			Secondary >20 years	n.a	n.a	n.a	
			Secondary ≤20 years	1.9	±90%	default	94

[1] Forest Resources Assessment (FRA). (2015). Global Eological Zones for FAO Forest Reporting 2010 Update. Forest Resources Assessment Working Paper 179.

[2] Some categories include sub-strata for primary forests, which are defined as old-growth forests that are intact or with no active human intervention, and secondary forests which include all other forests. The table considers a forest definition of at least 10% tree canopy cover (74).

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TABLE 4.8 (UPDATED)
ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})

Domain	Ecological Zone[1]	Continent	Species	Age (yr)	AGB (Tonnes d.m. ha^{-1})	SD	References
Tropical	Tropical rain forest	Africa	Broadleaf	≤20	100	±90%	10
		Africa	Broadleaf	>20	300	±90%	10
		Africa	*Pinus* sp.	≤20	60	±90%	10
		Africa	*Pinus* sp.	>20	200	±90%	10
		Americas	*Eucalyptus* sp.		200	±90%	10
		Americas	Other Broadleaf		150	±90%	10
		Americas	*Pinus* sp.		300	±90%	10
		Americas	*Tectona grandis*	>20	240	±90%	13
		Asia	*Acacia auriculiformis*	≤20	99-119	±90%	20
		Asia	*Acacia mangium*	<20	93.6	64.20	28
		Asia	Broadleaf		220	±90%	10
		Asia	*Dipterocarp* sp.	>20	452.2	149.90	14
		Asia	*Eucalyptus* sp.	≤20	46-161	43.70	20
		Asia	*Gmelina arborea*	<20	97.6	23.60	14
		Asia	*Hevea brasiliensis*	<20	113-132	±90%	18
		Asia	*Mangifera indica*	<20	13.5	4.90	7
		Asia	*Rhizophora sp.*	>20	152.2	±90%	1
		Asia	Mixed	>20	69	±90%	3
		Asia	Oil Palm	<20	18.4-35.4	±90%	33
		Asia	Oil Palm	>20	48.5	9.20	33
		Asia	*Paraserianthes falcataria*	<20	64.4	38.80	14
		Asia	*Sweitenia macrophylla*	>20	512.8	170.40	14
	Tropical moist deciduous	Africa	Broadleaf	>20	150	±90%	10
		Africa	Broadleaf	≤20	80	±90%	10
		Africa	*Rhizophora sp.*		111-483	±90%	34
		Africa	*Pinus* sp.	≤20	40-166	±90%	10,1
		Africa	*Tectona grandis*	<20	195.5	±90%	16
		Africa	*Tectona grandis*	>20	428.9	±90%	16
		Africa	*Pinus* sp.	>20	120-193.3	±90%	10,16
		Americas	*Anthocephalus chinensis*	<20	144	±90%	2
		Americas	*Coffea sp.*		46.9-57.5	±90%	15
		Americas	*Eucalyptus* sp.	>20	90	±90%	31
		Americas	Other Broadleaf		100	±90%	10
		Americas	*Pinus* sp.	>20	270	±90%	10

TABLE 4.8 (UPDATED) (CONTINUED)
ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA[-1])

Domain	Ecological Zone[1]	Continent	Species	Age (yr)	AGB (Tonnes d.m. ha^{-1})	SD	References
Tropical	Tropical moist deciduous	Americas	*Swietenia macrophylla*	<20	94	±90%	2
		Americas	*Swietenia macrophylla*	>20	121	±90%	2
		Americas	*Tectona grandis*	<20	84	±90%	24
		Americas	*Tectona grandis*	>20	284	±90%	24
		Asia	*Acacia auriculiformis*	>20	177	7.60	6
		Asia	*Acaica mangium*	>20	211	3.30	6
		Asia	Broadleaf	≤20	93.33-147.76	21.90	5
		Asia	Broadleaf	>20	107.05-224.48	55.60	5
		Asia	*Cassia montana*	<20	5.71	±90%	4
		Asia	*Cedeus libani*	≤20	15.1	±90%	8
		Asia	*Eucalyptus* sp.	<20	41.78	±90%	4
		Asia	*Eucalyptus* sp.	>20	260	97.40	6
		Asia	Oil Palm	<20	124-202	±90%	29
		Asia	Other		100	±90%	10
		Asia	*Swietenia macrophylla*	>20	193	17.00	6
		Asia	*Tectona grandis*	<20	121.88	±90%	9
		Asia	*Tectona grandis*	>20	93.72	64.70	6
	Tropical dry forest	Africa	Broadleaf	≤20	30	±90%	10
		Africa	Broadleaf	>20	70	±90%	10
		Africa	*Pinus* sp.	≤20	20-75.6	±90%	10,16
		Africa	*Pinus* sp.	>20	60-193.9	±90%	10,16
		Africa	*Tectona grandis*	<20	38.33	0.40	22
		Americas	*Eucalyptus* sp.		90	±90%	31
		Americas	Oil Palm	<20	40-62	±90%	26
		Americas	Oil Palm	>20	50-100	±90%	12
		Americas	Other Broadleaf		60	±90%	10
		Americas	*Pinus* sp.		110	±90%	10
		Americas	*Tectona grandis*		90	±90%	10
		Asia	*Acacia* sp.	<20	7.54-58.21	±90%	4
		Asia	*Adina cordifolia*		14.8	±90%	11
		Asia	*Adansonia digitata*		28.6	±90%	11
		Asia	*Albizia procera*	<20	4.9	±90%	11
		Asia	*Azadirachta indica*	<20	30.6-55.64	±90%	11,19
		Asia	*Bombax ceiba*		64.7	±90%	11
		Asia	Broadleaf		90	±90%	10

TABLE 4.8 (UPDATED) (CONTINUED) ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})							
Domain	**Ecological Zone[1]**	**Continent**	**Species**	**Age (yr)**	**AGB (Tonnes d.m. ha^{-1})**	**SD**	**References**
Tropical	Tropical dry forest	Asia	*Courapita guianensis*		5.5	±90%	11
		Asia	*Dalbergia sissoo*	≤20	11.07	6.79	35
		Asia	*Dendrocalamus strictus*	<20	48.2	±90%	19
		Asia	*Eucalyptus* sp.	≤20	21.67	±90%	37
		Asia	*Ficus* sp.		25.4	±90%	11
		Asia	*Gmelina arborea*	≤20	6.65	1.37	35
		Asia	*Leucaena leucocephala*	<20	53.35	±90%	19
		Asia	*Madhuca indica*		35.2	±90%	11
		Asia	*Mangifera indica*		24.2	±90%	11
		Asia	*Rhizophora sp.*	<20	125.5	2.60	25
		Asia	*Manilkara elengi*	<20	7.4	±90%	11
		Asia	*Miliusa tomentosa*	<20	4.8	±90%	11
		Asia	*Mitragyna parviflora*		18.1	±90%	11
		Asia	Other		60	±90%	10
		Asia	*Pongamia pinnata*	≤20	8.57	2.00	35
		Asia	*Populus deltoides*	<20	37.5	34.40	21
		Asia	*Prosopis juliflora*	<20	3.56	±90%	4
		Asia	*Salvadora oleoides*		12.2	±90%	11
		Asia	*Samanea saman*		30.9	±90%	11
		Asia	*Sterculia urens*	<20	8.2	±90%	11
		Asia	*Swietenia mahogani*		28.7	±90%	11
		Asia	*Tamarindus indica*		88.8	±90%	11
		Asia	*Tectona grandis*	<20	21.8	±90%	19
		Asia	*Terminalia* sp.	>20	45.5-71.1	±90%	11
		Asia	*Terminalia* sp.	<20	8.2	±90%	11
		Asia	*Ziziphus mauritiana*	<20	8	±90%	11
	Tropical shrubland	Africa	Broadleaf		20	±90%	10
		Africa	*Pinus sp.*	≤20	15	±90%	10
		Africa	*Pinus sp.*	>20	20	±90%	10
		Americas	*Eucalyptus* sp.		60	±90%	10
		Americas	Other Broadleaf		30	±90%	10
		Americas	*Pinus* sp.		60	±90%	10
		Americas	*Tectona grandis*		50	±90%	10
		Asia	*Acacia* sp.	≤20	11.78-47.99	±90%	27,32
		Asia	*Azadirachta indica*	≤20	53.32	±90%	32

TABLE 4.8 (UPDATED) (CONTINUED)
ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})

Domain	Ecological Zone[1]	Continent	Species	Age (yr)	AGB (Tonnes d.m. ha^{-1})	SD	References
Tropical	Tropical shrubland	Asia	Broadleaf		40	±90%	10
		Asia	Broadleaf	>20	263.3	±90%	17
		Asia	*Casuarina equisetifolia*	≤20	9.12	±90%	32
		Asia	Other		30	±90%	10
		Asia	*Pongamia pinnata*	≤20	9.03	±90%	32
		Asia	*Tectona grandis*	≤20	31.66	±90%	32
	Tropical mountain systems	Africa	*Broadleaf*	≤20	40-100	±90%	10
		Africa	Broadleaf	>20	60-150	±90%	10
		Africa	*Pinus* sp.	≤20	30-40	±90%	10
		Africa	*Pinus* sp.	>20	30-100	±90%	10
		Americas	*Eucalyptus* sp.		30-120	±90%	10
		Americas	Other Broadleaf		30-80	±90%	10
		Americas	*Pinus* sp.		60-170	±90%	10
		Americas	*Tectona grandis*		30-130	±90%	10
		Asia	Broadleaf		40-150	±90%	10
		Asia	Other		25-80	±90%	10
Sub-tropical	Subtropical humid forest	Americas	*Eucalyptus* sp.		140	±90%	10
		Americas	Other Broadleaf		100	±90%	10
		Americas	*Pinus* sp.		270	±90%	10
		Americas	*Tectona grandis*		120	±90%	10
		Asia	Broadleaf		180	±90%	10
		Asia	Other		100	±90%	10
		North America	*Populus sp.*	<20	23.07	20.40	36
		North America	*Eucalyptus* sp.	<20	2.45	2.99	36
		North America	Oaks and other hardwoods	<20	7.88	12.05	36
		North America	Oaks and other hardwoods	≥20	11.09	20.56	36
		North America	*Pinus* sp.	<20	19.65	17.01	36
		North America	*Pinus* sp.	≥20	45.53	24.66	36
	Subtropical dry forest	Africa	Broadleaf	≤20	30	±90%	10
		Africa	Broadleaf	>20	70	±90%	10
		Africa	*Pinus* sp.	≤20	20	±90%	10
		Africa	*Pinus* sp.	>20	60	±90%	10
		Americas	*Eucalyptus* sp.		110	±90%	10
		Americas	Other Broadleaf		60	±90%	10
		Americas	*Pinus* sp.		110	±90%	10
		Americas	*Tectona grandis*		90	±90%	10

TABLE 4.8 (UPDATED) (CONTINUED) ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})							
Domain	**Ecological Zone**[1]	**Continent**	**Species**	**Age (yr)**	**AGB (Tonnes d.m. ha^{-1})**	**SD**	**References**
Sub-tropical	Subtropical dry forest	Asia	Broadleaf	<20	69.45	48.89	39
		Asia	Broadleaf	>20	137.64	77.29	39
		Asia	Coniferous	<20	63.18	38.07	39
		Asia	Coniferous	>20	127.61	63.31	39
		Asia	*Cunninghamia* sp.	<20	62.96	37.38	39
		Asia	*Cunninghamia* sp.	>20	148.6	72.32	39
		Asia	*Eucalyptus* sp.	<20	68.72	55.05	39
		Asia	Other		60	±90%	39
		Asia	*Picea abies*	>20	138.23	47.42	39
		Asia	*Pinus massoniana*	<20	54.75	40.55	39
		Asia	*Pinus massoniana*	>20	163.45	66.07	39
	Subtropical steppe	Africa	Broadleaf		20	±90%	10
		Africa	*Pinus* sp.	≤20	15	±90%	10
		Africa	*Pinus* sp.	>20	20	±90%	10
		Americas	*Eucalyptus* sp.		60	±90%	10
		Americas	Other Broadleaf		30	±90%	10
		Americas	*Pinus* sp.		60	±90%	10
		Americas	*Tectona grandis*		50	±90%	10
		Asia	Broadleaf	≤20	10	±90%	10
		Asia	Broadleaf	>20	80	±90%	10
		Asia	Coniferous	≤20	100-120	±90%	10
		Asia	Coniferous	>20	20	±90%	10
		North America	Oaks and other hardwoods	<20	3.59-8.75	±90%	36
		North America	*Pinus* sp.	<20	22.8	19.91	36
		North America	*Pinus* sp.	≥20	46.69	16.55	36
	Subtropical mountain systems	Asia	*Acer velutinum*	<20	90.03	±90%	23
		Asia	*Alnus subcordata*	<20	103.53	±90%	23
		Asia	*Arizone cypress*	<20	25.72	0.11	30
		Asia	*Robinia pseudoacacia*	<20	8.85	0.54	30
		Asia	*Pinus brutia*	<20	50.62	0.52	30
		Asia	*Fraxinus excelsior*	<20	56.07	±90%	23
		Asia	*Morus sp.*	<20	9.87	0.33	30
		Asia	*Pinus nigra*	≤20	20.05-38.46	±90%	23,8
		Asia	*Prunus avium*	<20	37.92	±90%	23
		Asia	*Quercus castanifolia*	<20	72.82	±90%	23

TABLE 4.8 (UPDATED) (CONTINUED)
ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})

Domain	Ecological Zone[1]	Continent	Species	Age (yr)	AGB (Tonnes d.m. ha^{-1})	SD	References
Sub-tropical	Subtropical mountain systems	Asia	*Tilia begonifolia*	<20	71.88	±90%	23
		North America	*Pseudotsuga menziesii*	<20	53.93	±90%	36
		North America	Oaks and other hardwoods	<20	3.68	4.53	36
		North America	*Pinus* sp.	<20	14.51	14.54	36
		North America	*Pinus* sp.	≥20	24.87	25.85	36
		Africa	Broadleaf	≤20	40-100	±90%	10
		Africa	Broadleaf	>20	60-150	±90%	10
		Africa	*Pinus* sp.	≤20	10-40	±90%	10
		Africa	*Pinus* sp.	>20	30-100	±90%	10
		Americas	*Eucalyptus* sp.		30-120	±90%	10
		Americas	Other Broadleaf		30-80	±90%	10
		Americas	*Pinus* sp.		60-170	±90%	10
		Americas	*Tectona grandis*		30-130	±90%	10
		Asia	Broadleaf		40-150	±90%	10
		Asia	Other		25-80	±90%	10
Temperate	Temperate oceanic forest	Asia, Europe	Broadleaf	≤20	30	±90%	10
		Asia, Europe	Broadleaf	>20	200	±90%	10
		Asia, Europe	Coniferous	≤20	40	±90%	10
		Asia, Europe	Coniferous	>20	150-250	±90%	10
		North America	*Populus sp.*	≥20	76.19	51.72	36
		North America	*Pseudotsuga menziesii*	<20	15.35	18.86	36
		North America	*Pseudotsuga menziesii*	≥20	95.8	73.39	36
		North America	*Pinus* sp.	<20	3.87	±90%	36
		North America	*Pinus* sp.	≥20	131.27	143.75	36
		South America	Coniferous		90-120	±90%	10
	Temperate continental forest and mountain systems	Asia, Europe	Broadleaf	≤20	15	±90%	10
		Asia, Europe	Broadleaf	>20	200	±90%	10
		Asia, Europe	Coniferous	≤20	25-30	±90%	10
		Asia, Europe	Coniferous	>20	150-200	±90%	10
		North America	Coniferous		50-300	±90%	10
		North America	Coniferous		50-300	±90%	10
		South America	Coniferous		90-120	±90%	10
	Temperate continental forest	North America	*Populus sp.*	<20	88.35	±90%	36
		North America	*Populus sp.*	≥20	55.71	14.47	36

TABLE 4.8 (UPDATED) (CONTINUED)
ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})

Domain	Ecological Zone[1]	Continent	Species	Age (yr)	AGB (Tonnes d.m. ha^{-1})	SD	References
Temperate	Temperate continental forest	North America	*Pseudotsuga menziesii*	≥20	42.62-96.65	±90%	36
		North America	*Abies sp.*	<20	5.62	6.63	36
		North America	*Abies sp.*	≥20	21.49	10.62	36
		North America	Oaks and other hardwoods	<20	6.7	12.63	36
		North America	Oaks and other hardwoods	≥20	23.72	46.23	36
		North America	*Pinus* sp.	<20	31.45	28.87	36
		North America	*Pinus* sp.	≥20	80.94	68.21	36
		North America	*Picea sp.*	<20	9.89	8.14	36
		North America	*Picea sp.*	≥20	77.34	131.88	36
		Asia	*Larix* sp.	<20	57.49	32.16	39
		Asia	*Larix* sp.	>20	112.88	56.21	39
		Asia	*Pinus koraiensis*	<20	58.23	18.89	39
		Asia	*Pinus koraiensis*	>20	132.13	72.18	39
		Asia	*Pinus sylvestris*	<20	18	8.95	39
		Asia	*Pinus sylvestris*	>20	58.6	18.57	39
		Asia	*Pinus tabuliformis*	<20	34.02	14.15	39
		Asia	*Pinus tabuliformis*	>20	59.39	35.26	39
		Asia	*Poplar* sp.	<20	66.74	45.30	39
		Asia	*Robinia pseudoacacia*	<20	29.44	13.20	39
		Asia	*Robinia pseudoacacia*	>20	54.46	16.99	39
	Temperate mountain system	North America	*Populus sp.*	<20	55.98	±90%	36
		North America	Douglas fir	<20	13.56	18.81	36
		North America	Douglas fir	≥20	89.22	71.32	36
		North America	*Abies sp.*	<20	3.02	3.11	36
		North America	*Abies sp.*	≥20	40.48	71.99	36
		North America	Oaks and other hardwoods	<20	3.77	5.76	36
		North America	*Pinus* sp.	<20	6.93	14.26	36
		North America	*Pinus* sp.	≥20	29.07	35.39	36
		North America	*Picea sp.*	<20	5.92	11.25	36
		North America	*Picea sp.*	≥20	50.27	38.11	36
		Asia	*Acacia crassicarpa*	<20	31.5	±90%	38
		Asia	*Castanopsis hystrix*	<20	16.6	±90%	38

TABLE 4.8 (UPDATED) (CONTINUED)
ABOVEGROUND BIOMASS (AGB) IN FOREST PLANTATIONS (TONNES D.M. HA^{-1})

Domain	Ecological Zone[1]	Continent	Species	Age (yr)	AGB (Tonnes d.m. ha^{-1})	SD	References
Temperate	Temperate mountain system	Asia	*Eucalyptus sp.*	<20	34.6	±90%	38
		Asia	Mixed Plantation	<20	19.2	±90%	38
	Temperate steppe	North America	*Populus sp.*	≥20	51.8-60.05	±90%	36
		North America	*Quercus* and other hardwoods	≥20	41.06	29.99	36
		North America	*Pinus* sp.	<20	48.57	65.55	36
		North America	*Pinus* sp.	<20	4.75	6.72	36
		North America	*Pinus* sp.	≥20	84.88	24.75	36
		North America	*Pinus* sp.	≥20	3.6	4.70	36
Boreal	Boreal coniferous forest and mountain systems	Asia, Europe	Coniferous	≤20	5	±90%	10
		Asia, Europe	Coniferous	>20	40	±90%	10
		North America	Coniferous		40-50	±90%	10
	Boreal tundra woodland	Asia, Europe	Coniferous	≤20	5	±90%	10
		Asia, Europe	Coniferous	>20	25	±90%	10

[1] Forest Resources Assessment (FRA). (2015). Global Eological Zones for FAO Forest Reporting 2010 Update. Forest Resources Assessment Working Paper 179.

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TABLE 4.9 (UPDATED)
ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})

Domain	Ecological Zone[4]	Continent	Status/ Condition	Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]	Uncertainty	Uncertainty type	References
Tropical	Tropical rainforest	Africa	Primary	1.3	3.5	SD	1, 2
			Secondary> 20 years	3.5	3.3	SD	3-8
			Secondary≤ 20 years	7.6	5.9	SD	3-7, 9
		North and South America	Primary	1.0	2.0	SD	2, 10, 11
			Secondary> 20 years	2.3	1.1	SD	3, 4, 12-15
			Secondary≤ 20 years	5.9	2.5	SD	3, 4, 6, 12-14
		Asia	Primary	0.7	2.2	SD	2, 16
			Secondary> 20 years	2.7	3.1	SD	3, 4, 17
			Secondary≤ 20 years	3.4	3.9	SD	3, 4, 17-19
	Tropical moist deciduous forest	Africa	Primary[6]	0.4	±90%	default	
			Secondary> 20 years	0.9	0.7	SD	20, 21
			Secondary≤ 20 years	2.9	1.0	SD	20, 21
		North and South America	Primary	0.4	2.1	SD	2, 10, 11
			Secondary> 20 years	2.7	1.7	SD	3, 4, 12, 13, 15, 22
			Secondary≤ 20 years	5.2	2.3	SD	3, 4, 12, 13, 22
		Asia	Primary	0.4	±90%	default	7
			Secondary> 20 years	0.9	±90%	default	8
			Secondary≤ 20 years	2.4	0.3	SD	3, 4
	Tropical dry forest	Africa	Primary	-	-	-	
			Secondary> 20 years	1.6	±90%	default	9
			Secondary≤ 20 years	3.9	±90%	default	10
		North and South America	Primary	-	-	-	
			Secondary> 20 years	1.6	1.1	SD	12, 13
			Secondary≤ 20 years	3.9	2.4	SD	12, 13, 23

TABLE 4.9 (UPDATED) (CONTINUED) ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})							
Domain	**Ecological Zone[4]**	**Continent**	**Status/ Condition**	**Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]**	**Uncertainty**	**Uncertainty type**	**References**
Tropical	Tropical dry forest	Asia	Primary	-	-	-	
			Secondary> 20 years	1.6	±90%	default	11
			Secondary≤ 20 years	3.9	±90%	default	12
	Tropical shrublands	Africa	Primary	0.9 (0.2-1.6)*	±90%	default	24
			Secondary> 20 years	0.9 (0.2-1.6)*	±90%	default	24
			Secondary≤ 20 years	0.2-0.7	±90%	default	24
		North and South America	Primary	1.0*	±90%	default	24
			Secondary> 20 years	1.0*	±90%	default	24
			Secondary≤ 20 years	4.0	±90%	default	24
		Asia (Continental)	Primary	1.3 (1.0-2.2)*	±90%	default	24
			Secondary> 20 years	1.3 (1.0-2.2)*	±90%	default	24
			Secondary≤ 20 years	5.0	±90%	default	24
		Asia (insular)	Primary	1.0*	±90%	default	24
			Secondary> 20 years	1.0*	±90%	default	24
			Secondary≤ 20 years	2.0	±90%	default	24
	Tropical mountain system	Africa	Primary	0.5	±90%	default	13
			Secondary> 20 years	1.8	±90%	default	14
			Secondary≤ 20 years	5.5	6.8	SD	25-27
		North and South America	Primary	0.5	1.9	SD	2, 10, 11
			Secondary> 20 years	1.8	0.8	SD	3, 4, 12, 13
			Secondary≤ 20 years	4.4	1.6	SD	3, 4, 12, 13, 22
		Asia	Primary	-0.7	3.1	SD	2, 16
			Secondary> 20 years	1.1	0.4	SD	3, 4, 28, 29
			Secondary≤ 20 years	2.9	0.1	SD	3, 4, 28-30

TABLE 4.9 (UPDATED) (CONTINUED)
ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})

Domain	Ecological Zone[4]	Continent	Status/ Condition	Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]	Uncertainty	Uncertainty type	References
Sub-tropical	Subtropical humid forest	Africa	Primary	-	-	-	
			Secondary >20 years	1.0	±90%	default	15
			Secondary ≤20 years	2.5	±90%	default	16
		North and South America	Primary	-	-	-	
			Secondary >20 years	1.0	±90%	default	17
			Secondary ≤20 years	2.5	±90%	default	18
		Asia	Primary	-	-	-	
			Secondary >20 years	1.0	0.9	SD	3, 4, 31
			Secondary ≤20 years	2.5	0.8	SD	3, 4, 31
	Subtropical dry forest	Africa	Primary	1.8 (0.6-3.0)*	±90%	default	24
			Secondary >20 years	1.8 (0.6-3.0)*	±90%	default	24
			Secondary ≤20 years	2.4 (2.3-2.5)	±90%	default	24
		North and South America	Primary	1.0*	±90%	default	24
			Secondary >20 years	1.0*	±90%	default	24
			Secondary ≤20 years	4.0	±90%	default	24
		Asia (continental)	Primary	1.5*	±90%	default	24
			Secondary >20 years	1.5*	±90%	default	24
			Secondary ≤20 years	6.0	±90%	default	24
		Asia (insular)	Primary	2.0*	±90%	default	24
			Secondary >20 years	2.0*	±90%	default	24
			Secondary ≤20 years	7.0	±90%	default	24
	Subtropical steppe	Africa	Primary	0.9 (0.2-1.6)*	±90%	default	24
			Secondary >20 years	0.9 (0.2-1.6)*	±90%	default	24
			Secondary ≤20 years	1.2 (0.8-1.5)	±90%	default	24
		North and South America	Primary	1.0*	±90%	default	24
			Secondary >20 years	1.0*	±90%	default	24
			Secondary ≤20 years	4.0	±90%	default	24

TABLE 4.9 (UPDATED) (CONTINUED) ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})							
Domain	**Ecological Zone[4]**	**Continent**	**Status/ Condition**	**Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]**	**Uncertainty**	**Uncertainty type**	**References**
Subtropical	Subtropical steppe	Asia (continental)	Primary	1.3 (1.0-2.2)*	±90%	default	24
			Secondary >20 years	1.3 (1.0-2.2)*	±90%	default	24
			Secondary ≤20 years	5.0	±90%	default	24
		Asia (insular)	Primary	1.0*	±90%	default	24
			Secondary >20 years	1.0*	±90%	default	24
			Secondary ≤20 years	2.0	±90%	default	24
	Subtropical mountain system	Africa	Primary	-	-	-	
			Secondary >20 years	0.5	±90%	default	19
			Secondary ≤20 years	2.5	±90%	default	20
		North and South America	Primary	-	-	-	
			Secondary >20 years	0.5	±90%	default	21
			Secondary ≤20 years	2.5	±90%	default	22
		Asia	Primary	-	-	-	
			Secondary >20 years	0.5	0.3	SD	3, 4, 32
			Secondary ≤20 years	2.5	0.03	SD	3, 4, 32
Temperate	Oceanic	New Zealand	Primary	0.37	±0.85	95%CI	33
			Secondary >20 years	2.12	±0.82	95%CI	33
			Secondary ≤20 years	3.12	0.83	SE	34
		Europe	All	2.3	-	-	35
		North and South America	Secondary >20 years	9.1	20.2	SD	36
			Secondary ≤20 years	6.3	7.4	SD	36
	Continental	North and South America	Secondary >20 years	3.6	15.0	SD	36
			Secondary ≤20 years	3.3	5.2	SD	36
	Mountain	North and South America	Secondary >20 years	4.4	100.7	SD	36
			Secondary ≤20 years	3.1	3.6	SD	36

TABLE 4.9 (UPDATED) (CONTINUED)
ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})

Domain	Ecological Zone[4]	Continent	Status/ Condition	Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]	Uncertainty	Uncertainty type	References
Temperate	Desert	North and South America	Secondary >20 years	0.6	0.9	SD	36
			Secondary ≤20 years	0.5	1.2	SD	36
	Steppe	North and South America	Secondary >20 years	3.5	13.3	SD	36
			Secondary ≤20 years	2.3	3.2	SD	36
Boreal	Coniferous	Asia, Europe, North America	All	0.1-2.1	-	-	35
	Tundra woodland	Asia, Europe, North America	All	0.4	(0.2-0.5)	Range	24
	Mountain	Asia, Europe, North America	Primary or secondary >20 years	1.1-1.5	-	-	24
			Secondary ≤20 years	1.0-1.1	-	-	24

[1] Aboveground net biomass growth is defined as net change in total aboveground biomass over time. In this respect, both forest productivity and mortality are accounted for.

[2] Some categories include sub-strata for primary forests defined as old growth forests that are intact or with no active human intervention, and secondary forests which include all other forests. The table considers a forest definition of at least 10% tree canopy cover.

[3] For above-ground biomass growth rates with no standard deviation, IPCC Tier 1 default uncertainties apply.

[4] Forest Resources Assessment (FRA). (2015). *Global Eological Zones for FAO Forest Reporting 2010 Update. Forest Resources Assessment Working Paper 179.*

Observations on ecological zone and continent columns

Above-ground biomass growth rate was taken from: Tropical moist deciduous forest - North and South America (Primary); Tropical moist deciduous forest - North and South America (Primary); Tropical moist deciduous forest - Africa (Secondary>20 years); Tropical dry forest – North and South America (Secondary>20 years); Tropical dry forest – North and South America (Secondary≤20 years); Tropical dry forest – North and South America (Secondary>20 years); Tropical dry forest – North and South America (Secondary≤20 years); Tropical mountain system – North and South America (Primary); Tropical mountain system – North and South America (Secondary>20 years); Subtropical humid forest – Asia (Secondary>20 years); Subtropical humid forest – Asia (Secondary≤20 years)

Subtropical humid forest – Asia (Secondary>20 years); Subtropical humid forest – Asia (Secondary≤20 years); Subtropical mountain system – Asia (Secondary>20 years); Subtropical mountain system – Asia (Secondary≤20 years); Subtropical mountain system – Asia (Secondary>20 years); Subtropical mountain system – Asia (Secondary≤20 years).

Note: SD = standard deviation, CI = confidence interval, SE = standard error.

*****Recommendation based on IPCC 2006 estimates for Forests > 20 years.

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TABLE 4.10 (UPDATED)
ABOVE-GROUND NET BIOMASS GROWTH IN TROPICAL AND SUB-TROPICAL PLANTATION FORESTS (TONNES D.M. HA^{-1} YR^{-1})

Domain	Ecological zone[1]	Continent	Species	Above-ground biomass [tonnes d.m. ha^{-1} yr^{-1}]	Range [tonnes d.m. ha^{-1} yr^{-1}][2]	References
Tropical	Tropical rainforest	Africa	*Pinus* sp. ≤ 20 y	20		1
			Other ≤ 20 y	6	5-8	1
		North and South America	*Eucalyptus* sp.	20	6-40	1
			Pinus sp.	20		1
			Tectona grandis	15		1
			Other broadleaf	20	5-35	1
		Asia	*Eucalyptus* sp.	5	4-8	1
			Other	5	2-8	1
	Tropical moist deciduous forest	Africa	*Eucalyptus* sp. >20 y	25		1
			Eucalyptus sp. ≤20 y	20		1
			Other ≤ 20 y	9	3-15	1
		North and South America	*Eucalyptus* sp.	16		2
			Tectona grandis	8	4-12	1
			Other broadleaf	6-20	6-20	3
		Asia		8		1
	Tropical dry forest	Africa	*Eucalyptus* sp. ≤20 y	13		1
			Pinus sp. > 20 y	9	7-10	4
			Pinus sp. ≤ 20 y	6	5-8	4
			Other ≤ 20 y	10	4-20	1
		North and South America	*Eucalyptus* sp.	20	6-30	1
			Pinus sp.	7	4-10	1
			Tectona grandis	8	4-12	1
			Other broadleaf	10	3-12	1
		Asia	*Eucalyptus* sp.	15	5-25	1
			Other	7	2-13	1
	Tropical shrubland	Africa	*Eucalyptus* sp. >20 y	8	5-14	1
			Eucalyptus sp. ≤20 y	5	3-7	1
			Pinus sp. > 20 y	2.5		1
			Pinus sp. ≤ 20 y	3	0.5-6	1
			Other > 20 y	10		1
			Other ≤ 20 y	15		1
		North and South America	*Eucalyptus* sp.	20		1
			Pinus sp.	5		1
		Asia		6	1-12	1

TABLE 4.10 (UPDATED) (CONTINUED)
ABOVE-GROUND NET BIOMASS GROWTH IN TROPICAL AND SUB-TROPICAL PLANTATION FORESTS (TONNES D.M. HA^{-1} YR^{-1})

Domain	Ecological zone[1]	Continent	Species	Above-ground biomass [tonnes d.m. ha^{-1} yr^{-1}]	Range [tonnes d.m. ha^{-1} yr^{-1}][2]	References
Tropical	Tropical mountain systems	Africa		10		1
		North and South America	Eucalyptus sp.	10	8-18	1
			Pinus sp.	10		1
		Asia	Tectona grandis	2		1
			other broadleaf	4		1
			Eucalyptus sp.	3		1
			Other	5	1-10	1
Sub-tropical	Subtropical humid forest	North and South America	Eucalyptus sp.	20	6-32	1
			Pinus sp.	7	4-10	1
			Tectona grandis	8	4-12	1
			Other broadleaf	10	3-12	1
		Asia		8		1
	Subtropical dry forest	Africa	Eucalyptus sp. ≤20 y	13		1
			Pinus sp. > 20 y	10		1
			Pinus sp. ≤ 20 y	8		1
			Other ≤ 20 y	10	4-20	1
		North and South America	Eucalyptus sp.	20	6-30	1
			Pinus sp.	7	4-10	1
			Tectona grandis	8	4-12	1
			Other broadleaf	10	3-12	1
		Asia	Eucalyptus sp.	15	5-25	1
			Other	7	2-13	1
	Subtropical steppe	Africa	Eucalyptus sp. >20 y	8	5-14	1
			Eucalyptus sp. ≤20 y	5	3-7	1
			Pinus sp. > 20 y	2.5		1
			Pinus sp. ≤ 20 y	3	0.5-6	1
			Other > 20 y	10		1
			Other ≤ 20 y	15		1
		North and South America	Eucalyptus sp.	20		1
			Pinus sp.	5		1
		Asia		6	1-12	1
	Subtropical mountain systems	Africa		10		1
		North and South America	Eucalyptus sp.	10	8-18	1
			Pinus sp.	10		1
			Tectona grandis	2		1
			Other broadleaf	4		1

TABLE 4.10 (UPDATED) (CONTINUED)
ABOVE-GROUND NET BIOMASS GROWTH IN TROPICAL AND SUB-TROPICAL PLANTATION FORESTS (TONNES D.M. HA^{-1} YR^{-1})

Domain	Ecological zone[1]	Continent	Species	Above-ground biomass [tonnes d.m. ha^{-1} yr^{-1}]	Range [tonnes d.m. ha^{-1} yr^{-1}][2]	References
Subtropical	Subtropical mountain systems	Asia	Eucalyptus sp.	3		1
			Other	5	1-10	1
Temperate	Continental	North and South America	Secondary >20 years	4	5	5
			Secondary ≤20 years	5	4	5
	Mountain	North and South America	Secondary >20 years	9	7	5
			Secondary ≤20 years	10	86	5
	Oceanic	North and South America	Secondary >20 years	10	8	5
			Secondary ≤20 years	6	4	5
	Steppe	North and South America	Secondary >20 years	11	56	5
			Secondary ≤20 years	4	3	5
Boreal	Coniferous	Asia, Europe, North America	Secondary >20 years	1.0		1
			Secondary ≤20 years	1.0		1
	Tundra woodland	Asia, Europe, North America	Secondary >20 years	0.4		1
			Secondary ≤20 years	0.4		1
	Mountain	Asia, Europe, North America	Secondary >20 years	1.0		1
			Secondary ≤20 years	1.0		1

[1] Forest Resources Assessment (FRA). (2015). Global Eological Zones for FAO Forest Reporting 2010 Update. Forest Resources Assessment Working Paper 179.

[2] If a single estimate is included in this column it refers to the standard deviation of the mean estimate.

References

1IPCC 2003; 2Stape et al., 2004; 3Lugo et al., 1990; 4Masota et al 2016; 5June 18, 2018. Forest Inventory and Analysis Database, St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station (Available only on internet: http://apps.fs.fed.us/fiadb-downloads/datamart.html).

TABLE 4.11 (UPDATED)
REPORTED MEAN ANNUAL INCREMENT (GROWTH RATE OF MERCHANTABLE VOLUME) VALUES FOR SOME PLANTATION FOREST SPECIES (M^3 HA^{-1} YR^{-1})

Continent	Region/Country	Tree species	Plantation Purpose	MAI min	MAI max	S.D.2	Reference
World	General	*Acacia auriculiformis*	Productive	6	20	3.5	5, 8
		Acacia mearnsii	Productive	14	25	2.8	5, 8
		Araucaria angustifolia	Productive	8	24	4.0	5, 8
		Araucaria cunninghamii	Productive	10	18	2.0	5, 8
		Casuarina equisetifolia	Productive	6	20	3.5	5, 8
		Casuarina junghuhniana	Productive	7	11	1.0	5, 8
		Cordia alliodora	Productive	10	20	2.5	5, 8
		Cupressus lusitanica	Productive	8	40	8.0	5, 8
		Dalbergia sissoo	Productive	5	8	0.8	5, 8
		Eucalyptus camaldulensis	Productive	15	30	3.8	5, 8
		Eucalyptus deglupta	Productive	14	50	9.0	5, 8
		Eucalyptus globulus	Productive	10	40	7.5	5, 8
		Eucalyptus grandis	Productive	15	50	8.8	5, 8
		Eucalyptus robusta	Productive	10	40	7.5	5, 8
		Eucalyptus saligna	Productive	10	55	11.3	5, 8
		Eucalyptus urophylla	Productive	20	60	10.0	5, 8
		Gmelina arborea	Productive	12	50	9.5	5, 8
		Leucaena leucocephala	Productive	30	55	6.3	5, 8
		Pinus caribaea var. *caribaea*	Productive	10	28	4.5	5, 8
		Pinus caribaea var. *hondurensis*	Productive	20	50	7.5	5, 8
		Pinus oocarpa	Productive	10	40	7.5	5, 8
		Pinus patula	Productive	8	40	8.0	5, 8
		Pinus radiata	Productive	10	50	10.0	5, 8
		Swietenia macrophylla	Productive	7	30	5.8	5, 8
		Tectona grandis	Productive	6	18	3.0	5, 8
		Terminalia ivorensis	Productive	8	17	2.3	5, 8
		Terminalia superba	Productive	10	14	1.0	5, 8
Africa	General	*Acacia mellifera*	Productive	2.2	4.0	0.5	6, 8
		Acacia nilotica	Productive	15.0	20.0	1.3	6, 8
		Acacia senegal	Productive	1.4	2.6	0.3	6, 8
		Acacia seyal	Productive	2.0	6.0	1.0	6, 8

TABLE 4.11 (UPDATED) (CONTINUED)
REPORTED MEAN ANNUAL INCREMENT (GROWTH RATE OF MERCHANTABLE VOLUME) VALUES FOR SOME PLANTATION FOREST SPECIES (M^3 HA^{-1} YR^{-1})

Continent	Region/ Country	Tree species	Plantation Purpose	MAI min	MAI max	S.D.2	Reference
Africa	General	*Ailanthus excelsa*	Productive	6.6	9.4	0.7	6, 8
		Bamboos	Productive	5.0	7.5	0.6	6, 8
		Cupressus spp.	Productive	15.0	24.0	2.3	6, 8
		Eucalyptus spp.	Productive	12.0	14.0	0.5	6, 8
		Khaya spp.	Productive	8.5	12.0	0.9	6, 8
		Tectona grandis	Productive	2.5	3.5	0.3	6, 8
		Acacia albida	Productive semi-natural	4.0	6.1	0.5	6, 8
		Acacia mellifera	Productive semi-natural	1.9	3.5	0.4	6, 8
		Acacia nilotica	Productive semi-natural	12.5	20.0	1.9	6, 8
		Acacia senegal	Productive semi-natural	1.1	2.4	0.3	6, 8
		Acacia seyal	Productive semi-natural	1.8	3.2	0.4	6, 8
		Acacia tortilis	Productive semi-natural	1.2	3.7	0.6	6, 8
		Acacia tortilis var. *siprocarpa*	Productive semi-natural	1.5	2.4	0.2	6, 8
		Balanites aegyptiaca	Productive semi-natural	1.2	1.5	0.1	6, 8
		Sclerocarya birrea	Productive semi-natural	1.5	1.7	0.1	6, 8
		Ziziphus mauritiana	Productive semi-natural	0.9	1.0	0.0	6, 8
		Acacia mellifera	Protective	2.0	6.0	1.0	6, 8
		Acacia nilotica	Protective	13.0	21.0	2.0	6, 8
		Acacia senegal	Protective	1.4	2.8	0.4	6, 8
		Acacia seyal	Protective	1.9	4.3	0.6	6, 8
		Ailanthus spp.	Protective	6.0	12.0	1.5	6, 8
		Bamboos	Protective	4.0	8.0	1.0	6, 8
		Cupressus spp.	Protective	14.0	20.0	1.5	6, 8
		Eucalyptus spp.	Protective	10.0	14.0	1.0	6, 8
		Khaya spp.	Protective	7.0	16.0	2.3	6, 8
		Tectona grandis	Protective	5.0	8.0	0.8	6, 8
	E and S	*Acacia mearnsii / melanoxylon*	Productive	10	12	0.5	6, 8
	N	*Acacia nilotica*	Productive	15	20	1.3	6, 8
	N	*Acacia nilotica*	Productive semi-natural	12.5	20	1.9	6, 8
	N	*Acacia senegal*	Productive	1.4	2.6	0.3	6, 8
	N	*Acacia senegal*	Productive semi-natural	1.1	2.4	0.3	6, 8
	N	*Acacia seyal*	Productive	2	6	1.0	6, 8
	N	*Acacia seyal*	Productive semi-natural	1.8	3.2	0.4	6, 8
	E and S	*Eucalyptus grandis*	Productive	18	24	1.5	6, 8

TABLE 4.11 (UPDATED) (CONTINUED) REPORTED MEAN ANNUAL INCREMENT (GROWTH RATE OF MERCHANTABLE VOLUME) VALUES FOR SOME PLANTATION FOREST SPECIES (M^3 HA^{-1} YR^{-1})							
Continent	**Region/ Country**	**Tree species**	**Plantation Purpose**	**MAI min**	**MAI max**	**S.D.2**	**Reference**
Africa	E and S	*Eucalyptus nitens*	Productive	22	28	1.5	6, 8
	N	*Eucalyptus* spp.	Productive	12	14	0.5	6, 8
	E and S	*Pinus elliottii*	Productive	12	18	1.5	6, 8
	N and C	*Pinus elliottii*	Productive	7	8	0.3	6, 8
	N	*Pinus halapensis*	Productive semi-natural	1	2	0.3	6, 8
	Africa	*Pinus patula*	Productive	12	18	1.5	6, 8
	Africa	*Pinus pinaster*	Productive semi-natural	1	2	0.3	6, 8
	Africa	*Pinus radiata*	Productive	12	16	1.0	6, 8
	Congo	*Eucalyptus* spp.	Experimental	13.8	25	2.8	10
Asia	Asia	*Eucalyptus camaldulensis*	Productive	21.0	43.0	5.5	6, 8
	Asia	*Pinus* spp.	Productive	4.0	15.0	2.8	6, 8
	S and SE	*Acacia mangium*	Productive	19	40	5.3	6, 8
	E and S	*Castanea molissima*	Productive	1	6	1.3	6, 8
	E and S	*Cunninghamia lanceolata*	Productive	2.5	13.5	2.8	6, 8
	E and S	*Cunninghamia lanceolata*	Productive semi-natural	2.5	13.5	2.8	6, 8
	E	*Eucalyptus* spp.	Productive	1.6	8.7	1.8	6, 8
	S and SE	*Eucalyptus* spp.	Productive	7	12	1.3	6, 8
	S and SE	*Eucalyptus* spp.	Productive semi-natural	8	12	1.0	6, 8
	W and C	*Eucalyptus* spp.	Productive	4	10	1.5	6, 8
	Asia	*Pinus massoniana*	Productive semi-natural	2.8	16.3	3.4	6, 8
	Asia	*Populus* spp. and cultivars	Productive	3.7	18.5	3.7	6, 8
	Asia	*Populus* spp. and cultivars	Productive semi-natural	3.7	17.7	3.5	6, 8
	Asia	*Populus* spp. and cultivars	Productive	5	12	1.8	6, 8
	Asia	*Tectona grandis*	Productive	4	17.3	3.3	6, 8
	Asia	*Tectona grandis*	Productive semi-natural	4	6	0.5	6, 8
	China	*Dalbergia sissoo*	Productive	4	6	0.5	1
	China	*Eucalyptus* spp.	Productive	8	12	1.0	1
	China	*Gmelina arborea*	Productive	10	15	1.3	1
	China	*Acacia nilotica*	Productive	3	4	0.3	1
	China	*Populus* spp.	Productive	20	25	1.3	1
	China	*Tectona grandis*	Productive	0.6	7	1.6	1
	Turkey	*Pinus pinaster*	Productive	9.8	22.4	3.2	4
	Turkey	*Eucalyptus camaldulensis*	Productive	18.3	24.1	1.5	4

TABLE 4.11 (UPDATED) (CONTINUED)
REPORTED MEAN ANNUAL INCREMENT (GROWTH RATE OF MERCHANTABLE VOLUME) VALUES FOR SOME PLANTATION FOREST SPECIES (M^3 HA^{-1} YR^{-1})

Continent	Region/ Country	Tree species	Plantation Purpose	MAI min	MAI max	S.D.2	Reference
Asia	Turkey	*Populus* spp. and cultivars	Productive	23.5	55.1	7.9	4
	Turkey	*Pinus brutia*	Productive	1	15.4	3.6	4
	Vietnam	*Acacia* hybrid	Experimental	24.4	39.4	3.8	3
	Vietnam	*Acacia mangium*	Productive	11	23	3.0	9
	Vietnam	*Melia azedarach*	Productive	15	17	0.5	9
Europe	Europe	*Fagus sylvatica*	Productive	4	14	2.5	6, 8
	Europe	*Fagus sylvatica*	Productive semi-natural	2	14	3.0	6, 8
	Europe	*Larix decidua*	Productive	7	13	1.5	6, 8
	Europe	*Larix decidua*	Productive semi-natural	2	11	2.3	6, 8
	Europe	*Picea abies*	Productive	3.5	6	0.6	6, 8
	Europe	*Picea abies*	Productive semi-natural	1.5	15	3.4	6, 8
	Europe	*Pinus pinaster*	Productive	4.7	13.8	2.3	6, 8
	Europe	*Pinus sylvestris*	Productive	2.5	14	2.9	6, 8
	Europe	*Pinus sylvestris*	Productive semi-natural	1	10	2.3	6, 8
	Europe	*Quercus robur*	Productive	3	9	1.5	6, 8
	Europe	*Quercus robur*	Productive semi-natural	1.5	10	2.1	6, 8
	Sweden	*Pinus sylvestris*	Productive semi-natural	3.3	5.3	0.5	7
	Sweden	*Picea abies*	Productive semi-natural	3.4	10	1.7	7
	Sweden	*Larix sibirica*	Productive semi-natural	4	5.9	0.5	7
	Sweden	*Pinus contorta*	Productive semi-natural	4.6	6.9	0.6	7
	Sweden	*Betula pendula*	Productive semi-natural	3	8	1.3	7
	Sweden	*Populus* spp. and cultivars	Productive semi-natural	12	16	1.0	7
	Sweden	*Quercus robur*	Productive semi-natural	3.9	5.2	0.3	7
	Finland	*Pinus sylvestris*	Productive semi-natural	2	5	0.8	7
	Finland	*Picea abies*	Productive semi-natural	3	7	1.0	7
	Finland	*Betula pendula*	Productive semi-natural	3	7	1.0	7
	Norway	*Pinus sylvestris*	Productive semi-natural	1.5	3.5	0.5	7
	Norway	*Picea abies*	Productive semi-natural	4	8.5	1.1	7
	Norway	*Picea sitchensis*	Productive semi-natural	12	18	1.5	7
North and Central America	North and Central America	*Pinus taeda*	Productive	9	10	0.3	6, 8
Oceania	Oceania	*Eucalyptus globulus*	Productive	15.6	25	2.4	6, 8
	Oceania	*Pinus radiata*	Productive	15.7	21	1.3	6, 8

TABLE 4.11 (UPDATED) (CONTINUED)
REPORTED MEAN ANNUAL INCREMENT (GROWTH RATE OF MERCHANTABLE VOLUME) VALUES FOR SOME PLANTATION FOREST SPECIES (M^3 HA^{-1} YR^{-1})

Continent	Region/ Country	Tree species	Plantation Purpose	MAI min	MAI max	S.D.2	Reference
South America	South America	*Tectona grandis*	Productive	7.3	17.3	2.5	6, 8
	South America	*Xylia xylocarpa*	Productive	3.0	8.8	1.5	6, 8
	South America	*Acacia* spp.	Productive	15.0	30.0	3.8	6, 8
	South America	*Araucaria angustifolia*	Productive	15.0	30.0	3.8	6, 8
	South America	*Eucalyptus* spp.	Productive	20.0	70.0	12.5	6, 8
	South America	*Hevea brasiliensis*	Productive	10.0	20.0	2.5	6, 8
	South America	*Mimosa scabrella*	Productive	10.0	25.0	3.8	6, 8
	South America	*Pinus* spp.	Productive	25.0	40.0	3.8	6, 8
	South America	*Populus* spp.	Productive	10.0	30.0	5.0	6, 8
	South America	*Tectona grandis*	Productive	15.0	35.0	5.0	6, 8
	South America	*Eucalyptus* spp.	Productive	15	70	13.8	6, 8
	South America	*Pinus radiata*	Productive	14	34	5.0	6, 8
	Brazil	*Khaya ivorensis*	Productive	18	25	1.8	11
	Brazil	*Schizolobium amazonicum*	Productive	10	33	5.8	2

[1] Updated and replaced former Table 4.11A and 4.11B from the *2006 IPCC Guidelines*

[2] Standard deviation estimated from the min and max estimates.

Note: E: East, S: South, N: North, SE: Southeast, W: West, C: Central

References

1Chuande, X., 2001; 2Cordeiro, et al., 2015; 3Dell, B., Daping X., Thu, P.Q.; 4Erkan, N., 2003; 5FAO, 2001; 6FAO, 2006; 7Haapanen, M., et al., 2015; 8IPCC, 2006; 9Kien, N.D., 2014; 10Nzila, J.D., et al., 2004; 11Silva, L.F., et al., 2016.

TABLE 4.12 (UPDATED)
BIOMASS VALUES FROM TABLES 4.7–4.10

Domain	Ecological zone[1]	Continent	Status/ condition	Above-ground biomass in natural forests (tonnes d.m. ha^{-1})[2]	Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})[3]	Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})[4]	Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})[5]
Tropical	Tropical rainforest	Africa	Primary	404.2	n.a.	1.3	n.a.
			Secondary >20 years	212.9	200-300	3.5	n.a.
			Secondary ≤ 20 years	52.8	60-100	7.6	5-8
		North and South America	Primary	307.1	n.a.	1.0	n.a.
			Secondary >20 years	206.4	150-300	2.3	5-40
			Secondary ≤20 years	75.7	150-300	5.9	5-40
		Asia	Primary	413.1	n.a.	0.7	n.a.
			Secondary >20 years	131.6	48.5-512.8	2.7	2-8
			Secondary ≤20 years	45.6	13.5-161	3.4	2-8
	Tropical moist deciduous forest	Africa	Primary	236.6	n.a.	0.4	n.a.
			Secondary >20 years	72.8	120-483	0.9	n.a.
			Secondary ≤ 20 years	72.8	40-195	2.9	3-15
		North and South America	Primary	187.3	n.a.	0.4	n.a.
			Secondary >20 years	131.0	46.9-284	2.7	4-20
			Secondary ≤20 years	55.7	46.9-195	5.2	4-20
		Asia	Primary	67.7	n.a.	0.4	n.a.
			Secondary >20 years	67.7	93.7-260	0.9	8
			Secondary ≤20 years	67.7	5.7-202	2.4	8
	Tropical dry forest	Africa	Primary	69.6	n.a.	n.a.	n.a.
			Secondary >20 years	69.6	60-193.9	1.6	6-13
			Secondary ≤ 20 years	69.6	20-75.6	3.9	4-20
		North and South America	Primary	127.5	n.a.	n.a.	n.a.
			Secondary >20 years	118.9	50-110	1.6	4-30
			Secondary ≤20 years	32.2	40-62	3.9	4-30

TABLE 4.12 (UPDATED) (CONTINUED) BIOMASS VALUES FROM TABLES 4.7–4.10							
Domain	**Ecological zone**[1]	**Continent**	**Status/ condition**	**Above-ground biomass in natural forests (tonnes d.m. ha^{-1})**[2]	**Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})**[3]	**Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})**[4]	**Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})**[5]
Tropical	Tropical dry forest	Asia	Primary	184.6	n.a.	n.a.	n.a.
			Secondary >20 years	184.6	45.5-88.8	1.6	2-25
			Secondary ≤20 years	184.6	3.56-125.5	3.9	2-25
	Tropical shrublands	Africa	Primary	48.4	n.a.	0.9	n.a.
			Secondary >20 years	48.4	20	0.9	2.5-14
			Secondary ≤ 20 years	48.4	15-20	0.2-0.7	3-7
		North and South America	Primary	71.5	n.a.	1.0	n.a.
			Secondary >20 years	71.5	30-60	1.0	5-20
			Secondary ≤20 years	71.5	30-60	4.0	5-20
		Asia	Primary	38.3	n.a.	1.0-1.3	n.a.
			Secondary >20 years	38.3	30-263.3	1.0-1.3	1-12
			Secondary ≤20 years	38.3	9.0-53.3	2.0-5.0	1-12
	Tropical mountain systems	Africa	Primary	190.0	n.a.	0.5	n.a.
			Secondary >20 years	190.0	30-150	1.8	10
			Secondary ≤ 20 years	190.0	30-100	5.5	10
		North and South America	Primary	195.0	n.a.	0.5	n.a.
			Secondary >20 years	184.4	30-170	1.8	8-18
			Secondary ≤20 years	75.9	30-170	4.4	8-18
		Asia	Primary	433.5	n.a.	-0.7	n.a.
			Secondary >20 years	66.4	25-150	1.1	1-10
			Secondary ≤20 years	66.4	25-150	2.9	1-10

TABLE 4.12 (UPDATED) (CONTINUED)
BIOMASS VALUES FROM TABLES 4.7–4.10

Domain	Ecological zone[1]	Continent	Status/ condition	Above-ground biomass in natural forests (tonnes d.m. ha^{-1})[2]	Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})[3]	Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})[4]	Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})[5]
Sub-tropical	Sub-tropical humid forests	Africa	Primary	54.1	n.a.	n.a.	n.a.
			Secondary >20 years	54.1	n.a.	1.0	n.a.
			Secondary ≤ 20 years	54.1	n.a.	2.5	n.a.
		North and South America	Primary	84.5	n.a.	n.a.	n.a.
			Secondary >20 years	84.5	11.1-270	1.0	3-32
			Secondary ≤20 years	84.5	2.45-270	2.5	3-32
		Asia	Primary	323.0	n.a.	n.a.	n.a.
			Secondary >20 years	258.4	100-180	1.0	8
			Secondary ≤20 years	258.4	100-180	2.5	8
	Sub-tropical dry forests	Africa	Primary	65.2	n.a.	1.8	n.a.
			Secondary >20 years	65.2	60-70	1.8	8
			Secondary ≤ 20 years	65.2	20-30	2.4	4-20
		North and South America	Primary	115.9	n.a.	1.0	n.a.
			Secondary >20 years	115.9	60-110	1.0	3-30
			Secondary ≤20 years	115.9	60-110	4.0	3-30
		Asia	Primary	70.9	n.a.	1.5-2.0	n.a.
			Secondary >20 years	70.9	60-163.5	1.5-2.0	2-25
			Secondary ≤20 years	70.9	54.8-69.5	6.0-7.0	2-25
	Sub-tropical dry forests	Africa	Primary	65.2	n.a.	1.8	n.a.
			Secondary >20 years	65.2	60-70	1.8	8
			Secondary ≤ 20 years	65.2	20-30	2.4	4-20
		North and South America	Primary	115.9	n.a.	1.0	n.a.
			Secondary >20 years	115.9	60-110	1.0	3-30
			Secondary ≤20 years	115.9	60-110	4.0	3-30

TABLE 4.12 (UPDATED) (CONTINUED)
BIOMASS VALUES FROM TABLES 4.7–4.10

Domain	Ecological zone[1]	Continent	Status/ condition	Above-ground biomass in natural forests (tonnes d.m. ha^{-1})[2]	Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})[3]	Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})[4]	Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})[5]
Sub-tropical	Sub-tropical dry forests	Asia	Primary	70.9	n.a.	1.5-2.0	n.a.
			Secondary >20 years	70.9	60-163.5	1.5-2.0	2-25
			Secondary ≤20 years	70.9	54.8-69.5	6.0-7.0	2-25
	Sub-tropical dry forests	Africa	Primary	65.2	n.a.	1.8	n.a.
			Secondary >20 years	65.2	60-70	1.8	8
			Secondary ≤ 20 years	65.2	20-30	2.4	4-20
		North and South America	Primary	115.9	n.a.	1.0	n.a.
			Secondary >20 years	115.9	60-110	1.0	3-30
			Secondary ≤20 years	115.9	60-110	4.0	3-30
		Asia	Primary	70.9	n.a.	1.5-2.0	n.a.
			Secondary >20 years	70.9	60-163.5	1.5-2.0	2-25
			Secondary ≤20 years	70.9	54.8-69.5	6.0-7.0	2-25
	Sub-tropical steppe	Africa	Primary	50.5	n.a.	0.9	n.a.
			Secondary >20 years	50.5	15-20	0.9	2.5-14
			Secondary ≤ 20 years	50.5	15-20	1.2	0.5-15
		North and South America	Primary	44.0	n.a.	1.0	n.a.
			Secondary >20 years	44.0	30-60	1.0	5-20
			Secondary ≤20 years	44.0	3.6-60	4.0	5-20
		Asia	Primary	41.6	n.a.	1.0-1.3	n.a.
			Secondary >20 years	41.6	20-80	1.0-1.3	1-12
			Secondary ≤20 years	41.6	10-120	2.0-5.0	1-12

TABLE 4.12 (UPDATED) (CONTINUED)
BIOMASS VALUES FROM TABLES 4.7–4.10

Domain	Ecological zone[1]	Continent	Status/ condition	Above-ground biomass in natural forests (tonnes d.m. ha^{-1})[2]	Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})[3]	Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})[4]	Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})[5]
Sub-tropical	Sub-tropical mountain systems	Africa	Primary	35.1	n.a.	n.a.	n.a.
			Secondary >20 years	35.1	30-150	0.5	10
			Secondary ≤ 20 years	35.1	10-100	2.5	10
		North and South America	Primary	74.6	n.a.	n.a.	n.a.
			Secondary >20 years	74.6	24.9-170	0.5	2-18
			Secondary ≤20 years	74.6	3.7-170	2.5	2-18
		Asia	Primary	250.2	n.a.	n.a.	n.a.
			Secondary >20 years	155.2	n.a.	0.5	1-12
			Secondary ≤20 years	155.2	8.9-103.5	2.5	1-12
Temperate	Mountain	Asia	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	170.4	n.a.	n.a.	3.0
			Secondary ≤ 20 years	n.a.	16.6-34.6	n.a.	3.0
		Europe	Primary	301.1	n.a.	n.a.	n.a.
			Secondary >20 years	214.7	n.a.	n.a.	3.0
			Secondary ≤20 years	27.8	n.a.	n.a.	3.0
		North and South America	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	185.9	29.1-89.2	4.4	9
			Secondary ≤20 years	57.9	3.0-56.0	3.1	10
	Continental	Asia	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	116	54.5-132.1	n.a.	4.0
			Secondary ≤ 20 years	90.9	18-66.7	n.a.	4.0
		Europe	Primary	332.4	n.a.	n.a.	n.a.
			Secondary >20 years	162	n.a.	n.a.	4.0
			Secondary ≤20 years	51.6	n.a.	n.a.	4.0

TABLE 4.12 (UPDATED) (CONTINUED)
BIOMASS VALUES FROM TABLES 4.7–4.10

Domain	Ecological zone[1]	Continent	Status/ condition	Above-ground biomass in natural forests (tonnes d.m. ha^{-1})[2]	Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})[3]	Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})[4]	Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})[5]
Temperate	Continental	North and South America	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	128.9	21.5-96.7	3.6	4
			Secondary ≤20 years	46	5.688.35	3.3	5
	Oceanic	Asia	Primary	289.8	n.a.	n.a.	n.a.
			Secondary >20 years	n.a.	150-200	n.a.	4.4
			Secondary ≤ 20 years	n.a.	30-40	n.a.	4.4
		Europe	Primary	126.1	n.a.	2.3	n.a.
			Secondary >20 years	153.9	150-200	2.3	4.4
			Secondary ≤20 years	22.3	30-40	2.3	4.4
		Oceania	Primary	352.7	n.a.	0.37	n.a.
			Secondary >20 years	120.5	n.a.	2.12	4.4
			Secondary ≤20 years	57.5	n.a.	3.12	4.4
		North and South America	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	354.1	76.2-131.3	9.1	10
			Secondary ≤20 years	213.9	3.9-120	6.3	6
	Desert	Asia Europe North and South America	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	44	n.a.	0.6	n.a.
			Secondary ≤20 years	25.6	n.a.	0.5	n.a.
	Steppe	Asia Europe North and South America	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	118.5	3.6-84.9	3.5	11
			Secondary ≤20 years	42.9	4.8-48.8	2.3	4

TABLE 4.12 (UPDATED) (CONTINUED)
BIOMASS VALUES FROM TABLES 4.7–4.10

Domain	Ecological zone[1]	Continent	Status/ condition	Above-ground biomass in natural forests (tonnes d.m. ha^{-1})[2]	Above-ground biomass in forest plantations (tonnes d.m. ha^{-1})[3]	Above-ground net biomass growth in natural forests (tonnes d.m. ha^{-1} yr^{-1})[4]	Above-ground net biomass growth in forest plantations (tonnes d.m. ha^{-1} yr^{-1})[5]
Boreal	Coniferous Tundra woodland Mountain	Asia Europe North America	Primary	62.9	n.a.	0.1-2.1	n.a.
			Secondary >20 years	n.a.	40-50	0.1-2.2	1.0
			Secondary ≤20 years	n.a.	5.0-50	0.1-2.3	1.0
		Asia Europe North America	Primary	n.a.	n.a.	0.4	n.a.
			Secondary >20 years	63.7	25	0.4	0.4
			Secondary ≤20 years	104.2	5	0.4	0.4
		Asia Europe North America	Primary	n.a.	n.a.	n.a.	n.a.
			Secondary >20 years	n.a.	40-50	1.1-1.5	1.0
			Secondary ≤20 years	1.9	5.0-50	1.0-1.1	1.0

[1] Forest Resources Assessment (FRA). (2015). Global Ecological Zones for FAO Forest Reporting 2010 Update. Forest Resources Assessment Working Paper 179.

[2] For information related to uncertainties and references refer to table 4.7

[3] For information related to uncertainties and references refer to table 4.8

[4] For information related to uncertainties and references refer to table 4.9

[5] For information related to uncertainties and references refer to table 4.10

Annex 4A-1 Glossary for Forest Land

No refinement.

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