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National Forestry Accounting Plan for Germany – annotated and revised edition

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Content

Vorbemerkung und Zusammenfassung

Die Mitgliedstaaten der EU sind nach EU-Verordnung 2018/841 (LULUCF-VO) verpflichtet, für die Zeiträume 2021 – 2025 und 2026 – 2030 einen *National Forestry Accounting Plan* (NFAP, nationaler Anrechnungsplan für die Forstwirtschaft) vorzulegen. Dieser muss jeweils das sogenannte *Forest Reference Level* (FRL, Referenzwert für Wälder) enthalten, gegen das die realen Veränderungen im Wald in diesem Zeitraum bilanziert und angerechnet werden sollen. Der deutsche NFAP wurde am 20.12.2019 fertiggestellt und eingereicht. Die Vorgaben der EU-Verordnung sind in sich jedoch nicht völlig widerspruchsfrei und in Teilen unterschiedlich interpretierbar, so dass je nach Gewichtung einzelner Aspekte unterschiedliche Methoden oder Datensätze „die besten verfügbaren" sind. Zwischen der EU-Kommission und Deutschland (und parallel anderen Mitgliedsstaaten) kam es deshalb zu intensiven Diskussionen um einzelne Punkte des jeweiligen NFAP. In der Folge stimmt deshalb das im ersten eingereichten Entwurf enthaltene FRL nicht mit dem des final eingereichten NFAP und dieses nicht mit dem des delegierten Rechtsaktes, der die FRL der Mitgliedsstaaten festschreibt, überein. Dieses letztlich zwischen Kommission und Deutschland vereinbarte FRL wurde formal als „Recalculation" seitens der EU verabschiedet. Da es keine formal korrekte Möglichkeit zur Überarbeitung des NFAP gibt, die diese Änderungen berücksichtigt und nicht alle Dokumente, die zwischen Deutschland und der EU-Kommission ausgetauscht wurden, frei verfügbar sind, legen wir hier eine kommentierte Fassung als Thünen-Working Paper vor, in dem die entsprechenden Rechengänge und die verwendeten Zahlen nachvollzogen werden können. Das Working Paper folgt in der Struktur so weit wie sinnvoll dem originalen NFAP, um die Nachverfolgung von Änderungen zu erleichtern. Es ist allerdings zu beachten, dass dieser Bericht formal nicht mit dem NFAP identisch ist und nicht als dieser referenziert werden darf. Der offiziell eingereichte NFAP ist auf der Homepage des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit hinterlegt:

https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/nfap_germany_bf.pdf

Dieser Bericht hat den Stand Sommer 2021. Die Berichterstattung entwickelt sich permanent weiter, Methoden werden verbessert, neue Daten werden verfügbar und durch z.B. technische Korrekturen in die Inventare eingebaut. Die aktuell laufenden Novellierungen sind hier nicht enthalten, da sie in den Nationalen Inventarberichten dokumentiert werden. Bei der Verwendung von Zahlen im NFAP-Kontext sind deshalb immer die letzten verfügbaren Nationalen Inventarberichte auf Änderungen zu prüfen. Dieser Bericht fokussiert auf Bearbeitungsschritte, die nicht so leicht zugänglich dokumentiert sind. Würde man auf die letzte Aktualisierung der THG-Berichterstattung warten, könnte der Bericht erst in einem Jahrzehnt publiziert werden.

Nicht alle Autoren des NFAP waren an dieser kommentierten und ergänzten Version beteiligt. Da der NFAP und alle Dokumente hierzu international sind, ist dieser Bericht im Weiteren in Englisch abgefasst.

Schlüsselworte: Forest Reference Level, LULUCF-Verordnung, Treibhausgasinventar, Projektion

Preliminary note and abstract

Following EU-Regulation 2018/841 (LULUCF-Reg.), the member states of the European Union are obliged to submit National Forestry Accounting Plans (NFAP), covering the periods 2021 – 2025 and 2026 – 2030. The NFAP must include a Forest Reference Level (FRL), which is used to estimate the net emissions of Greenhouse Gases to be accounted by the respective member state. The FRL of all member states were formally set by a delegated act from the Commission. The NFAP for Germany was submitted Dec. 12th, 2019. Because the requirements set by the LULUCF-Reg. are not completely self-consistent and competetive in parts, so depending on interpretation and weighing of the requirements, different methods or data sets are better suited than others. Following the first submission, intense discussion arose between the Commission and Germany (and, in parallel, some other member states). Thus, the FRL included in the first submission is not identical with the FRL in the final submission, and this is not identical with the FRL finally agreed upon and set in the delegated act. For formal reasons, the final FRL is set as a „recalculation“ by the Commission. There is no legal possibility to amend the submitted NFAP, and only part of the documents exchanged between Germany and the Commission are available to the public, so we decided to publish this Thünen Working Paper as a commented NFAP with additional explanations and information. The text follows the structure of the original NFAP as much as possible, to help readers to reproduce and understand the changes made by the Commission. In any case, this paper is not to be mistaken for and / or cited as the German NFAP. The officially submitted NFAP for Germany is available from the homepage of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety:

https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/nfap_germany_bf.pdf

This report is as at summer 2021. Greenhouse Gas Inventories evolve constantly as methods are refined and new data become available. This leads to technical corrections in the inventories. Refinements that are under way or planned as this report was drafted are not considered here. They are or will be documented in the National Inventory Reports (NIR). If numbers from the NFAP shall be used, please check with the NIRs whether these numbers have changed. This report focuses on changes whose documentation is not so openly accessible as the NIR. If this report would wait for the final actualization of the reporting, it could not be published for at least another decade.

Not all authors of the original NFAP contributed to this ammended version and are thus not listed as authors here.

Keywords: Forest Reference Level, EU-LULUCF-Regulation, Greenhouse Gas Inventory, Projection

Requirements for the FRL and the NFAP

The requirements for NFAPs are laid down in Annex IV of Reg. (EU) 2018/841:

ANNEX IV

NATIONAL FORESTRY ACCOUNTING PLAN CONTAINING A MEMBER STATE'S FOREST REFERENCE LEVEL

A. Criteria and guidance for determining forest reference level

A Member State's forest reference level shall be determined in accordance with the following criteria:

(a) the reference level shall be consistent with the goal of achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, including enhancing the potential removals by ageing forest stocks that may otherwise show progressively declining sinks;

(b) the reference level shall ensure that the mere presence of carbon stocks is excluded from accounting;

(c) the reference level should ensure a robust and credible accounting system that ensures that emissions and removals resulting from biomass use are properly accounted for;

(d) the reference level shall include the carbon pool of harvested wood products, thereby providing a comparison between assuming instantaneous oxidation and applying the first-order decay function and half-life values;

(e) a constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009 shall be assumed;

(f) the reference level should be consistent with the objective of contributing to the conservation of biodiversity and the sustainable use of natural resources, as set out in the EU forest strategy, Member States' national forest policies, and the EU biodiversity strategy;

(g) the reference level shall be consistent with the national projections of anthropogenic greenhouse gas emissions by sources and removals by sinks reported under Regulation (EU) No 525/2013;

(h) the reference level shall be consistent with greenhouse gas inventories and relevant historical data and shall be based on transparent, complete, consistent, comparable and accurate information. In particular, the model used to construct the reference level shall be able to reproduce historical data from the National Greenhouse Gas Inventory.

B. Elements of the national forestry accounting plan

The national forestry accounting plan submitted pursuant to Article 8 shall contain the following elements:

(a) a general description of the determination of the forest reference level and a description of how the criteria in this Regulation were taken into account;

(b) identification of the carbon pools and greenhouse gases which have been included in the forest reference level, reasons for omitting a carbon pool from the forest reference level determination, and demonstration of the consistency between the carbon pools included in the forest reference level;

(c) a description of approaches, methods and models, including quantitative information, used in the determination of the forest reference level, consistent with the most recently submitted national inventory report, and a description of documentary information on sustainable forest management practices and intensity as well as of adopted national policies;

(d) information on how harvesting rates are expected to develop under different policy scenarios;

(e) a description of how each of the following elements were considered in the determination of the forest reference level:

(i) the area under forest management;

(ii) emissions and removals from forests and harvested wood products as shown in greenhouse gas inventories and relevant historical data;

(iii) forest characteristics, including dynamic age-related forest characteristics, increments, rotation length and other information on forest management activities under 'business as usual';

(iv) historical and future harvesting rates disaggregated between energy and non-energy uses.

National Forestry Accounting Plan / Germany

Chapter 1: General Introduction

1.1 General description of the forest reference level for Germany

This National Forestry Accounting Plan has been prepared pursuant to Article 8 of REGULATION (EU) 2018/841 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework (hereafter referred to as: the Regulation), and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU and especially in accordance with the requirements set out in Annex IV B of the Regulation.

About 30% of Germany's area is forested and all forest lands are considered managed. The actual management and the management applied in the Reference Period are sustainable and in line with EU and national forest and natural resource use related policies (see Chapters 2 and 3 for details).

The German Forest Reference Level (FRL) has been estimated in accordance with the requirements and framing conditions set out in the Regulation. It contains all gases and pools given in Annex I of the Regulation.

The FRL was estimated to be net emissions of -10.0224 million tons CO_2-equivalent (i.e. a sink) per year in the first Compliance Period 2021 – 2025. This was replaced in the recalculation by -34.3669 million tons CO_2-equivalent.

1.2 Consideration to the criteria as set in Annex IV of the LULUCF Regulation

The German FRL is based on forest management practices conducted in the Reference Period (RP), i.e. in the years between 2000 and 2009. The German FRL is based on data from two subsequent forest inventories within the Reference Period, the reference years being 2002 and 2008, and thus on a stock change approach. The same forest plots were measured in both inventories and were allocated in age classes and volume classes in both years (2002 and 2008). This forms an age class / volume class crosstable for each of these years. In the European Forestry Dynamics Model (EFDM), which was used as a blueprint to develop the German model, this is called a state-space. The development of the carbon content in each forest stratum (i.e. tree age, volume class) in the reference period is used as a proxy for the management practices. These vectors (see Figure 1) are then applied to the state of the forest ahead of the commitment period, thereby taking into account the shifting age-class structure of the forest. In the construction of the FRL, the development of forest areas in the strata in the base period has been extrapolated until 2022 in order to take into account the age-related forest characteristics. From 2008 onwards, the same area transitions are repeated in five-year time steps to model future inventory intervals. The model applies the vectors at each step to the "new" distribution achieved by the previous modelling step. The areas in each cell of the state-space are split according to the transition vectors and the area in the „target cells“ is aggregated to derive the distribution of area at the subsequent simulated inventory date. The resulting distribution of forest area in the state-space thus describes the state of the forest after each time step. The resulting area distributions for the time steps 2012 (for transparency reasons only) is shown in Table 2. The 2017 matrix (as basis for 2018-2022) is shown in Table I-5 of Annex 1 of the NFAP and as same format (digits) as other tables here in Table 3, the one for 2022 (as basis for 2023-2027) is given in the following Table 2: Area [kha] distribution of age and volume classes at the end of step 2 (2012). Any deviation in the carbon content of a forest stratum in the commitment period 2021-2025 compared to the base period indicates a shift in the forest management and is included in the accounting of the forest sector.

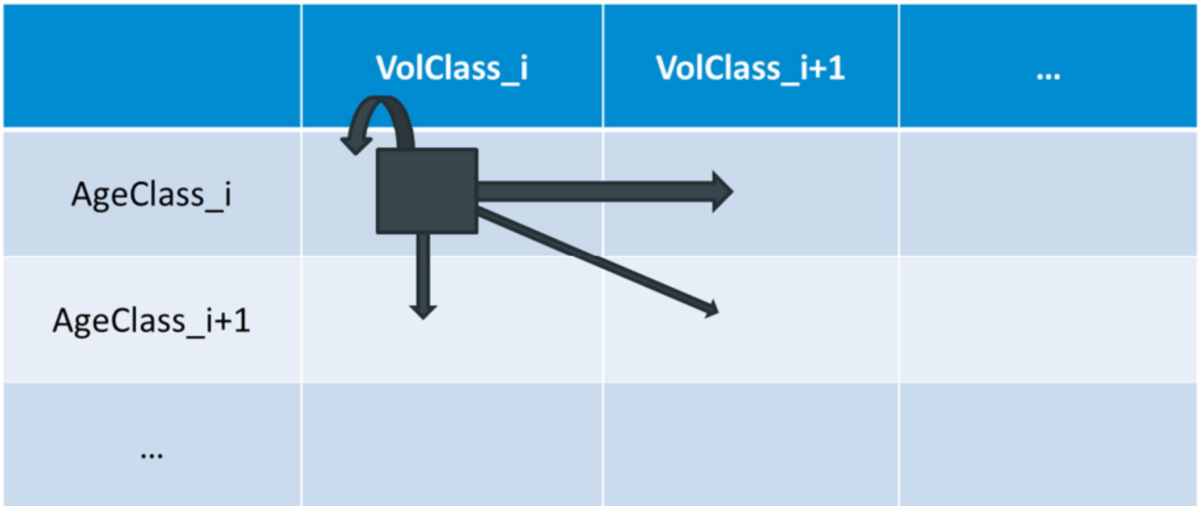

Figure 1: Visualisation of transition vectors in the age class – volume class matrix

In general, forest management in Germany is subject to rules, standards and regulations laid down both at Federal and state level, for example in the Federal Forest Act and equivalent acts and laws of the federal states (Länder). This results in a rather complex multi-level regulatory environment. Yet, they all aim to maintain productivity and health of the forest, its use for society, and its ecological services, including biodiversity. All public owned and privately owned forest estates larger than (in most states) 50 hectares are required to have forest inventories and management plans (planning horizon and level of detail will vary depending on state, size, type of ownership, etc.), which are checked for compliance with forest- and land use-related laws by the forest authorities of the Länder. The management conducted in the reference period was found to be sustainable by the standards and criteria of the MCPFE (Forest Europe 2015).

Due to the approach chosen for the German FRL, any assumptions about the future development of the forest management or of the forest sink cannot be taken into account. This ensures strict alignment with the reference period 2000-2009 as stipulated in Article 8(5) of the Regulation. Yet, this also implies that the criteria contained in Annex IV Part A Letter a (alignment with the aim of achieving a balance between emissions and removals) and Letter f (consideration of biodiversity and sustainability) can only be taken into account to an extent that can be derived from the reference period. Any strategies adopted after 2009 did not enter the calculation of the FRL. Meanwhile, these strategies are oriented towards the aims of safeguarding and increasing the forest sink, in line with the objective to reach a balance between emissions and removals, and to ensure a sustainable forest management.

The management applied in the reference period resulted in net removals in this period, as shown in the 3rd National Forestry Inventory (2012). Thus, the forest management assumed in the construction of the FRL as well as the resulting FRL can be considered as oriented towards “achieving a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century” as requested in Annex IV A (a) of the Regulation. They also contribute “to the conservation of biodiversity and the sustainable use of natural resources, as set out in the EU forest strategy, Member States' national forest policies, and the EU biodiversity strategy” as requested in Annex IV A (f), to the extent that the management applied in the compliance period did. Any further orientation of the FRL towards these goals would violate the requirement of “continuation of management” and was thus completely avoided by the approach chosen here. Forest management in the RP covered all age classes and, as shown in Annex I, table 2, yielded considerable removals by ageing forest stocks as called for in Annex IV (A) a of the Regulation. The calculation of the FRL is based on changes or rates of change for all pools considered, so the mere presence of carbon stocks is excluded from accounting as requested by Annex IV A (b) of the Regulation.

The FRL is also embedded in the existing and proven methods applied in the reporting framework used under the Convention, including the provisions on Harvested Wood Products (HWP), and is derived from and replicates historical data already included in the GHG Inventory and Reporting (i.e., data of the years 2002 to 2008), so the requirements of Annex IV A (c), (d), (g) and (h) of the Regulation are also fulfilled.

Chapter 2: Preamble for the forest reference level

2.1 Carbon pools and greenhouse gases included in the forest reference level

The German Forest Reference Level includes the following pools:

- above-ground (living) biomass
- below-ground (living) biomass
- litter
- dead wood
- soil organic carbon
- harvested wood products

and gases:

- CO_2
- CH_4
- N_2O

as requested by Annex I of the Regulation and as already reported under the Convention and currently accounted under the Protocol of Kyoto.

2.2 Demonstration of consistency between the carbon pools included in the forest reference level

See Chapter 3.

2.3 Description of the long-term forest strategy

2.3.1 Overall description of the forests and forest management in Germany and the adopted national policies

The state of Germany’s forests is documented in the National Forest Inventory, openly accessible at https://www.bundeswaldinventur.de. The latest full inventory was finalised in 2012 (BMEL 2015). Germany’s stocked forest land covers appr. 10.7 million hectares and is completely reported under the Convention in the respective land use category “Forest Land remaining Forest Land"[1]. All forests in Germany are considered to be under management and are thus covered by the approach chosen to estimate the FRL.

The legal frame for forest management in Germany is set by the Federal Forest Act and the Forest Acts of the Federal States. National forest-related policies include the National Forest Strategy 2020 (Waldstrategie 2020, BMELV 2011), the Charter for Wood (Charta für Holz 2.0, BMEL 2018), the Climate Action Plan 2050 (Klimaschutzplan 2050, BMUB 2016), and the National Strategy on Biological Diversity (Nationale Strategie zur biologischen Vielfalt, BMUB 2007). They all aim to maintain productivity and health of the forest, enhance its climate protection function, use for society, and biodiversity, to varying degrees, and focus on different main targets.

The Forest Strategy 2020 addresses complex interrelations between forests and society and different demands on forests. It identifies action areas and outlines the existing challenges and opportunities, analyses possible conflicts of interest and formulates potential solutions. The objective is to show ways of achieving a viable balance between the growing demands on forests and their sustainable productivity.

With the objectives of mitigating climate change, creating value and utilising resources efficiently, the Charter for Wood 2.0 focuses on qualitative growth to support central international, European and national political objectives. The use of wood as the most important renewable resource is of particular significance. Sustainably produced wood from structurally rich forests has the potential to increasingly replace materials produced on the basis of fossil resources and to conserve energy from finite resources while simultaneously mitigating climate change.

The Climate Action Plan of the Federal Government (BMUB 2016) includes a section on the sector land-use, land-use change and forestry which, inter alia, aims at "maintaining and improving the ability of forests to act as a sink." The LULUCF sector should thereby contribute to the economy-wide guiding principle of becoming virtually carbon-neutral by mid-century. It links to the Forestry Strategy 2020 and encourages a sustainable management of forests, aiming at forests' potential to take up and store CO_2, and the closely-associated use of wood, permanent grassland conservation, protection of peatlands and potential of natural forest development to mitigate climate change. The Climate Action Plan contains a range of forestry-related measures aimed at reaching these targets.

[1] It should be noted that the National Forest Inventory assesses the state of the forest, but the area of forest lands used in the GHG rporting framework is estimated from a land use matrix that uses a much denser inventory grid then the NFI and thus yields different overall area.

In the NFI 2012, 51 tree species or tree species groups are distinguished in German forests. More than 75% of the forest area is mixed forest (two or more species in the main canopy layer), and more than two thirds have two or more canopy layers or are selection forests (Plenterwald). Forests are owned by the federal government (3.5%, e.g. military training grounds), the federal states (29%), communities, municipalities, etc. (19%), and private persons or companies (48%). About half of the privately owned forest area is allocated to estates with less than 20 hectares of forest. This diverse ownership structure results in a multitude of management targets which, in combination with the very different ecological conditions in the different regions of Germany, lead to a multitude of management systems and management activities, even when the same tree species or species mixture is considered. In praxis, about every management schedule and / or activity mentioned in forest management textbooks (see e.g. Burschel & Huss (2003), Mayer (1992), Röhrig & Bartsch (1992) and Röhrig & Gussone (1990) for details) can be observed in German forestry.
It is therefore impossible to identify and describe Forest Management Practices as suggested by Forsell et al. (2018). Furthermore, it should be noted that a detailed description of forest management practices is not a precondition for the approach chosen by Germany for the construction of the FRL. Instead – as explained above – the FRL is entirely derived from the development of the carbon content of different forest strata during the base period in combination with the areas of the strata as a factor of the dynamic age-related forest characteristics. The development of the carbon content mirrors the management for each stratum without recurrence to empirically collected data on historic management practices in each forest stratum. Such a data collection would be extremely complex, prone to errors and possibly inaccurate, given the broad range of forest types, ownership structure and ecological conditions across Germany and the historic nature of the reference period.

2.3.2 Description of future harvesting rates under different policy scenarios

Projections of future forest management are available from the WEHAM 2012 base scenario (Schmitz et al. 2016) and a research project ("WEHAM-Szenarien", Oehmichen et al. (2018)). The WEHAM framework is scenario-driven and applies very different models than used in the construction of the FRL. Thus, the projections from both approaches are consistent insofar as they are based on the same set of data, but the results cannot be identical.

The base scenario describes forest and timber resource development for 2012 – 2052 based on the state of the forest as shown in the NFI 2012. The scenario is deducted from measurements (e.g. increments) and expert judgement on future harvest intentions of forest owners and managers. It is used in the WEM scenario of the Report to Regulation 525/2013 and an earlier version of the Base Scenario's management data are currently used for the Forest Management Reference Level under the Protocol of Kyoto. While the Base Scenario reflects the intentions and possibilities currently known and foreseeable, the scenarios applied in the „WEHAM-Szenarien" project are also based on the state of the forest in 2012, but describe alternative policies ("wood preference" and "nature conservation") and also a "business as usual"-scenario that keeps up trends etc. which were detectable in 2012. The scenarios have been developed with regard to stakeholder perspectives, but are research-oriented and do not reflect any officially adopted policies.

The wood-preference scenario aimed to reduce the volume of standing stock to the level of the NFI in 1987 (i.e., by appr. 14%) by reducing production times and target diameters in relation to the base scenario. To satisfy an (assumed) higher demand for timber in the future, the share of area of Douglas fir is significantly increased in rejuvenated stands, at the expense of spruce and pine.

The nature conservation-oriented scenario is aimed at increasing the share in area of current potential natural vegetation by converting stands of mainly spruce and pine, where currently they are not growing on their "natural" sites. Thus, the share of coniferous stands is decreased and that of broadleaved species increased. For trees growing on their natural sites, production times are also increased and, by this, standing timber volumes are raised.

The harvesting potentials of the three scenarios for the CPs are given in Table 1. Please note that these scenarios and the FRL originate from different methodological frameworks and have different underlying assumptions about harvest intensities and strategies. In particular, these scenarios try to forecast potential developments whereas the FRL continues observed management practices from the past. Therefore, the FRL does not equal any of the three scenarios and comparisons should take the methodological differences into account.

Table 1: Harvest (raw wood potential as useable timber, [Mio. m^3 a^{-1} (over bark)]) of three scenarios (Base: Base Scenario, WPS: wood preference scenario, NCS: nature conservation-oriented scenario)

CP	Base	WPS	NCS
2021-2025	76.95	115.94	83.62
2026-2030	74.61	116.76	79.88

Chapter 3: Description of the modelling approach

3.1 Description of the general approach as applied for estimating the forest reference level

Germany applies a stock-difference method in GHG reporting and applies a comparable approach in constructing the FRL (described as "alternative approach" in Box 12 of Forsell et al. 2018). Changes in the different pools during the RP have been determined individually per pool and are also modelled (for the CP) per pool. The development of the living biomass and the amount of harvested wood is modelled using the approach described in Annex I and the calculation framework of the NFI already used in the German GHG Inventory and Reporting. The use of the stock difference method assures that all forest characteristics mentioned in Annex IV B (e) III of the Regulation are implicitly regarded without having to be addressed individually. The Regulation requests, to avoid the inclusion of influences from outside the RP, that data from outside the RP should not be used to estimate the FRL, if data from within the RP are available. Congruously, Germany used data from the NFI 2002 and the Carbon Inventory 2008 to calculate emission factors for living biomass in the RP. This led to a comparatively low FRL, since during these years more wood (and carbon) was extracted from the living biomass pool than in the years prior to and following the RP, due to timber market developments in the first years of this period and severe windstorms in 2007. The Commission thus asked to include the reported emissions of the years 2000, 2001, 2008, and 2009 in the estimation. Due to the stock difference approach that is used in the German NGHGI, the emissions reported for the respective years are the mean annual emissions for the period between the first and the second NFI (1987 / 1990 to 2002) and the period between the Inventory Study and the third NFI (2008 – 2012). Germany had explicitly decided against such an approach (which is also argued against in Forsell et al. 2018), because this violates the requirements set in the Regulation. As a compromise, it was agreed to recalculate the net emissions from living biomass with annualized values from the respective years, calibrated with annually reported harvest data following the method described in Röhling et al. (2016). This led to a recalculation of the amount of harvested wood, too, which is used to estimate the changes in the HWP pool with the model WoodCarbonMonitor (Rüter 2017). Because of the requirement of coherence between FRL and GHG reporting, Germany also had to change the reporting under the Convention accordingly and report annualized values (starting with the NIR 2021). Emissions from changes in the dead wood pool and from forest fires were initially assumed to be equal to the mean from the RP (NFAP first draft), but then calculated in accordance with the NIR as projections from the data reported up to 2018.This had not been clearly communicated in the submitted NFAP. The development of the litter pool was modelled together with soil carbon in Yasso15 (for details, see Ziche et al. 2019). This was in anticipation of a change in SOC estimation intended for the NGHGI starting with the NIR 2020. The COM insisted on using the approach currently applied in the NGHGI, i.e. a linear projection of the SOC changes estimated in the first and second National Forest Soil Inventories (NFSI). This led to a severe change in the FRL. Since the third NFSI will not be finalized until the end of the first compliance period (2021 – 2025), SOC net emission factors contained in the NIR and the FRL will be identical in any case, leading to no accountable changes in SOC (in neither direction). Details on the different models and simulators are given in the most recent NIR and Annexes I and II.

Assumptions concerning climate change

In preparing the FRL it was assumed that climate change between the RP and the CP does not influence net emissions or removals from any pool significantly. Climate trends present in the data from the RP are indirectly included in the parametrization and modelling of the FRL, e.g. influences of changes in climate on tree increment. This is considered to be in line with the "business as usual" requirement. Soil carbon in mineral soils and litter and dead wood were modelled in a project where climate scenario data were employed (Ziche et al. 2019). Since this approach was rejected by COM, the FRL set in the Delegated Act does not consider climate change. For the other pools, no models are available that incorporate climate data, and, because these pools are far less sensitive to climatic drivers than e.g. litter decomposition, there is no need to include climate data when projections span only comparatively short time frames.

Assumptions concerning area of Managed Forest Land

For the FRL, the area of managed forest land (MFL) is equal to the area of "forest land remaining forest land" taken from the most recent NIR. This was the NIR 2020, but COM insisted on using the NIR 2019, because this was the most recent NIR publicly available at the time of the submission of the NFAP. The following changes in the area of MFL are considered: for deforestation (which is subject to legal permission in Germany), the projected value is set to zero. This way, all deforestation is assured to be accounted for. With regard to afforestation, the respective area of afforested land is added to MFL after a 20 year transition period. This increase in area was only considered for the estimation of living biomass, all other pools were estimated (in the recalculation done by COM) based on the average area of the reference period (10,607,070 ha). Emissions and removals for HWP are independent of area.

Starting year of projection

The starting years of the simulations are given in the respective parts of Annex I and II.

Assumptions concerning Harvested Wood Products

The projection of emissions and removals arising from the HWP pool is implemented with the computer model WoodCarbonMonitor already used for the German GHG inventory reporting. It is documented in the NIR 2019 and in Rüter (2017). In order to derive the contribution of the HWP pool to emissions and removals in the FRL, the applied approach follows the steps described in Sections 2.3.5 and 2.5.6 of Forsell et al. (2018). The time series of harvest amounts (i.e. harvest as loss of timber) projected by the forest management model are thus used as input parameter for the HWP calculation. In a first step, annual rates of change of the projected harvest amounts as compared to the historic average within the RP (2000 to 2009) are derived. In a second step, these annual rates of change are applied to the average historic carbon inflow during the RP to the HWP pool within the three relevant HWP commodity classes, which represent the material use of wood (i.e. sawnwood, wood-based panels and paper and paperboard). The subsequent calculations of future emissions and removals arising from the HWP pool are conducted in exactly the same way as for the GHG inventory reporting, thus full methodological consistency between FRL and the GHG Inventories is ensured.

For this purpose, the projected harvest amounts are estimated on the basis of the average annual harvest as loss of timber per ha of the strata (Table I-6 in Annex I) during the RP weighed by the area in each stratum at the start of the CP (Table I-8, I - 9). This leads to an adjusted overall harvest as loss of timber (in reserve solid cubic metres, RSCM) within the CP (Table I-). A constant ratio between solid and energy use of forest biomass as documented in the period from 2000 to 2009 is ensured as follows: During the RP, the average annual harvest for the purpose of the use of wood as material (industrial roundwood) was 47.814 Mio. m^3. This equals 46.2% of the total harvest as loss of timber (in RSCM) during the RP from the forest, which amounts to 103.54 Mio. RSCM on annual average. This latter value is calculated by calibrating the time series on harvest (2000 – 2009) from the national logging statistics (Federal Statistical Office, 2019) by means of inventory information on the annual loss of timber (in RSCM) during the entire RP (2000 – 2009). In consequence, the total annual harvest losses considered here is not equal to the value shown in table I-4. The calibration of the harvest statistics is necessary since it under-estimates the annual logging by around 30%, inter alia due to the production of firewood by private households, which is statistically not recorded. The complementary 53.8% of total harvest as loss of timber during the RP are thus assumed to be used as wood for energy and the projected annual amount of timber harvested for the purpose of the use of wood as material (i.e. industrial roundwood) during the CP sums up to 51.749 Mio. m^3 on average (see Table 1-10). This is consistent with the projected carbon inflow to the HWP pool within the three relevant HWP commodity classes, which represent the material use of wood during the CP.

The changes in the estimation of carbon in living biomass and the associated harvest as compared to the submitted NFAP, also led to adjustments of the HWP calculations. In consequence, the ratio for harvest (0.984, see Table 1 for adjustments of the reference period to 2000-2009) was applied to both 5-year cycles of the matrix model and the weighted average for the compliance period 2021-2025 (Table 2).

Table 2: Adjustments in HWP inflow in reference period and compliance period.

Period	Harvest for HWP-inflow, reference period 2002-2007 [Mio. RSCM yr^{-1}]	Harvest for HWP-inflow, reference period 2000-2009 [Mio. RSCM yr^{-1}]
2018-2022	112.1*	110.2
2023-2027	112.5**	110.6
2021-2025	112.3	**110.5**

RSCM…reserve solid cubic meters
*Corresponds to total in table I-6 of German NFAP.
**Estimate provided by Germany.

As result, the value for HWP emissions with application of the adjustment proposed for the CP (2021-2025) is -8,157,029 t CO_2.

3.2 Documentation of data sources as applied for estimating the forest reference level

The FRL is based on data gathered by the National Forest Inventory 2002, the Inventory Study 2008, the National Forest Soil Inventories I (1987 – 1994) and II (2004 - 2008) and the Forest fire statistics (2001-2017).

3.2.1 Documentation of stratification of the managed forest land

For the purpose of estimating the FRL the managed forest land was stratified by volume class (of growing stock) and age class (20 yrs.) as described in detail in Annex I.

3.2.2 Documentation of sustainable forest management practices as applied in the determination of the forest reference level

The objective of sustainable Forest Management in Germany is defined as "permanently and optimally secure the diverse economic, ecological and social benefits of the forest for the use of the present and future generations." (BMEL 2015). The basic principles are laid down in the Federal Forest Act and the respective Forest Acts and Laws of the Länder and other laws concerning the use of natural resources. The enforcement of the respective rules and regulations is in the hands of the responsible authorities in the Federal States (Länder). All public owned and privately owned forest estates larger than (in most states) 50 hectares are required to have forest inventories and management plans (planning horizon and level of detail will vary depending on state, size, type of ownership, etc.), which are also checked for compliance with forest- and land use-related laws by the forest authorities of the Länder. In addition, between 70 % and 80 % of Germany's managed forest lands were subject to certification by either FSC, PEFC (or both), or NATURLAND (BMEL 2017). The forest management practices applied in Germany in the RP were also found to be sustainable with regard to the criteria set out by the MCPFE (Forest Europe 2015) and as assessed by the UNECE / FAO Forestry and Timber Section (UNECE 2017). Thus, forest management in Germany was sustainable in the RP and thereafter.

Future management is influenced by e.g. the Strategies and Programmes presented in Section 2.3.1. Although these are not considered in the FRL estimation, they aim to develop a sustainable balance between the increasing demands on forests and their sustainable performance, adapted to future requirements. This information is given for transparency only, since the approach to calculate the FRL chosen by Germany does not require any distinction by or description of FMP in the reference period or thereafter (as explained above).

3.3 Detailed description of the modelling framework as applied in the estimation of the forest reference level

The modelling is conducted in several steps: First, the annual change of above- and belowground biomass is modelled in volume class / age class strata, using the stock-difference approach and the same algorithms and functions as in the existing GHG Inventory (see Annex I for details). In the same step, the amount of harvested wood is projected (see Annex I) and used as input in the modelling of the HWP pool with the model Wood Carbon Monitor. The development of the litter and the soil carbon pools of mineral soils were projected based on measurements covering the RP, and projections for net emissions from organic soils and dead wood were added (see Annex II for details). Net emissions from forest fires were projected based on the trend in burnt area from the NIR and included CO_2, which is included here since 2017, whereas COM used the mean burnt area during the RP in their “recalculation”. During the RP, CO_2-emissions from forest fires were reported “ie”. The emissions from dead wood were also projected based on the trend in the NIR, whereas COM stated they used the average emissions from the RP as given in NIR 2019. Thus, values for both pools deviate between the submitted NFAP (which was in accordance with the then-current NIR) and the “recalculation” by COM.

Natural disturbances

To date, Germany does not intend to apply the Natural Disturbance provision laid down in Article 10 of the Regulation. Any changes in GHG stocks in the forest are considered to be management-related.

Chapter 4: Forest reference level

4.1 Forest reference level and detailed description of the development of the carbon pools

In the submitted NFAP, the aggregated FRL for Germany was estimated to be net emissions of -10.0224 million tons CO_2-equivalent per year in the first Compliance Period 2021 – 2025. With the recalculation applied, this changed to **-**34,366,906 t CO2e yr^{-1}**.** The contribution of the individual pools considered here are given in Table 3.

Table 3: Overview of annual net emissions from different pools in the first CP (2021 – 2025) including recalculations

Carbon pool or source of non-CO_2 gases	Reported in revised NFAP (1)	Recalculation method	
	(t CO_2e yr^{-1})	(t CO_2e yr^{-1})	Method used
Living biomass	-7,085,000	-9,680,607	EF for 2000-2009 based on Roehling et al (2016) for the projected state of the forest in the compliance period
Mineral soil and litter	3,873,800	-15,309,647	As an approximation for the development of the pools in the absence of changes in forest management: Net emissions and removals assumed for compliance period, expressing the average 2000-2009 values from the GHGI 2019.
Organic soils and 4(II)	2,846,800	912,138	
Dead wood	-1,081,000	-2,135,723	
Forest fires	30,000	3,962	
HWP	-8,607,000	-8,157,029	Recalculation contributed by Germany due to the methodological changes as demonstrated in section 3.4
FRL excluding HWP	**-1,415,400**	**-26,209,877**	
FRL including HWP	**-10,022,400**	**-34,366,906**	

(1) Table 2 and II-1 of Germany's NFAP 2019

4.2 Consistency between the forest reference level and the latest national inventory report

Consistency between the FRL and the latest national inventory report is assured by using the same methodological framework and the same data sources (see above and Annex I – II for details).

4.3 Calculated carbon pools and greenhouse gases for the forest reference level

See 4.1 and Annex I and II.

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National Forest Accounting Plan for Germany – Annex I

Modelling framework for projecting the Forest Reference Level

Part I: above- and belowground biomass – “alternative Approach”

I.1 Background

The European Parliament and the Council of the European Union have adopted a Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU (REGULATION (EU) 2018/841 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018).

The Regulation inter alia requests member states to account for the impact of forest management (or human induced emissions from forestland and its management) for the time after 2020 until 2030, subdivided into the compliance periods (CP) (2021-2025 and 2026-2030). For managed forest lands the common approach proposed by the Regulation is based on the construction of a forward-looking baseline, so called forest reference level (FRL).

This should be based on the continuation of sustainable forest management practices (Art. 8 (5) of the Regulation) from a reference period (RP, 2000 - 2009). In addition, any double counting of removals or emissions is to be avoided (Art. 5 (2)) and the mere presence of carbon stocks has to be excluded from accounting (Annex IV A (b)).

The Regulation especially notes that country-specific characteristics should be reflected and that the best available data should be used in the construction of the FRL. Consistency between the methods and data used to determine the proposed forest reference level and those used in the GHG reporting for managed forest land needs to be ensured.

The FRL should take into account relevant historical data and shall be based on transparent, complete, consistent, comparable and accurate information. In particular, the model used to construct the reference level shall be able to reproduce historical data from the National Greenhouse Gas Inventory.

Germany uses the stock difference method to estimate emissions and removals in forests in the GHG Inventories. The method employed to calculate the FRL is based on the stock changes in forest strata in the RP. It follows the “alternative approach” described in Forsell et al. (2018), a guidance document recommended by COM, because the structure of Germanys forests (tree species, site conditions, mixture, horizontal and vertical structure, type of ownership, estate size, management objectives, …) is so variable and diverse that no uniform forest management practices or, e.g., stratum-specific “rotation lengths” can possibly be determined.

I.2 Stratification of managed forest land

The GHG reporting on land generally follows a simple approach: activity data (AD, here: areas of forests) are multiplied by emission factors (EF, here: net emissions from particular carbon pools per unit of activity data) to calculate resulting emissions. In the German GHG Inventory, the EF for (living) biomass for Forest Land remaining Forest Land is calculated following the stock-difference method from two consecutive forest inventories. As there is no stratification in the GHG Inventory that could be used in constructing the FRL, data from the NFI 2002 are used for stratification purposes instead, i.e. the combination of standing volume classes and age classes (Table I-1, I - 2). Germany’s forest has more than 150 tree species although only about 10 dominate the forest and generate most of the goods and services, including tree species in the stratification results in large variation. In the German NFI, age classes of 20 years are also standard for age-related classifications. Since management is more correlated to standing stocks and stock density than age, the forest was classed in 15 volume classes (0-<50, 50 – <100, …, >=700 m^3 ha^{-1}).

This kind of classification is used to provide in-depth information on the situation of forests and it also represents the distribution of dynamic age-related characteristics at the time of the inventory. The differences between two consecutive inventories yield the differences in carbon stocks, which can be expressed as an EF per hectare of forest that was in a specific stratum at the start of the period (Table I-3, Figure I - 1). It reflects the impact of the forest management (and, eventually, natural disturbances) on this class regarding net emissions or removals per unit of activity data in the class (area).

Table I-1: Area [kha] distribution of volume classes at the beginning of the RP (NFI 2002), rounded (this table was amended due to rounding-related issues with the presentation of the numbers).

	volume class [m^3 ha^{-1}]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	865.034	140.481	82.911	27.149	6.396	1.565	1.589	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1,125.125
21 - 40	117.661	254.742	266.598	256.514	226.596	197.955	103.765	95.707	81.314	27.335	26.995	6.399	11.087	14.421	4.832	1,691.922
41 - 60	46.371	86.555	181.637	223.306	283.924	274.288	309.664	207.569	170.776	138.947	68.514	49.446	41.582	30.460	46.357	2,159.396
61 - 80	14.418	57.506	84.872	153.246	174.021	167.685	188.591	188.505	146.937	135.830	97.302	92.685	59.154	36.828	110.588	1,708.166
81 –100	14.285	24.022	60.708	78.470	115.227	172.194	153.660	121.246	151.917	126.152	125.155	92.815	62.286	62.155	196.646	1,556.939
101 - 120	1.604	30.445	33.629	49.497	80.089	107.327	106.800	90.836	108.664	91.457	78.413	67.202	54.521	44.807	134.678	1,079.970
121 - 140	0.000	4.801	20.786	33.646	25.497	46.318	59.107	36.844	54.195	51.097	44.692	33.776	32.089	25.542	73.786	542.175
141 - 160	3.277	4.789	14.399	11.108	17.582	19.163	27.209	33.397	28.746	14.358	22.375	22.458	11.193	9.610	23.862	263.527
> 160	6.369	3.187	9.637	11.227	15.846	9.686	9.609	4.787	9.485	7.963	4.805	8.012	12.764	8.001	14.390	135.768

Table I -2: Area [kha] distribution of age and volume classes at the end of the RP (NFI subsample 2008)

	volume class [m³ ha⁻¹]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	758.415	118.001	70.156	33.534	19.180	8.003	1.598	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1,008.888
21 - 40	132.271	219.985	215.808	218.337	196.090	146.909	108.845	92.583	48.101	33.562	23.954	12.762	8.057	6.399	4.806	1,468.468
41 - 60	47.724	106.852	156.026	269.438	234.521	299.879	252.161	216.772	170.293	150.100	103.667	75.121	51.069	28.734	78.297	2,240.654
61 - 80	38.316	39.929	106.878	131.079	178.730	175.717	175.861	210.876	175.531	110.266	79.675	81.594	75.020	39.968	104.154	1,723.593
81 –100	14.453	30.193	68.800	76.523	132.979	137.302	178.958	151.856	151.924	110.375	116.788	100.870	76.694	49.639	177.344	1,574.699
101 - 120	7.948	17.575	35.240	48.097	107.085	107.375	119.890	127.733	96.048	94.679	99.227	57.324	64.004	55.960	141.105	1,179.290
121 - 140	0.000	16.074	25.510	38.261	28.740	36.632	70.300	57.463	55.851	65.473	52.714	33.497	33.685	28.990	70.585	613.775
141 - 160	0.000	4.795	9.580	14.421	25.558	11.210	17.603	27.213	39.864	28.582	17.599	25.630	15.930	6.417	35.135	279.538
> 160	6.369	9.583	15.917	12.783	14.376	11.132	11.262	15.939	14.295	7.992	6.398	14.496	4.789	6.395	22.357	174.084
total	1,.005.496	562.987	703.915	842.474	937.258	934.160	936.479	900.436	751.908	601.028	500.023	401.293	329.248	222.502	633.784	10,262.990

Table I-3: EFs [t CO_2-eq.ha^{-1} a^{-1}] during the RP by forest classes, living biomass (trees, above- and belowground, rounded values; amended (decimals added))

	volume class [m³ ha^{-1}]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	-11.00	-14.75	-13.88	-9.66	2.23	-16.29	-13.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-11.59
21 - 40	-8.91	-11.17	-11.66	-9.12	-10.56	-8.98	-1.90	-3.61	5.15	-10.67	-11.50	2.81	-20.30	-11.16	- 22.34	-8.70
41 - 60	-6.40	-10.48	-7.30	-8.99	-7.11	-5.03	-4.94	-4.00	-4.33	0.21	2.92	4.07	-0.66	-9.11	22.80	-4.56
61 - 80	-6.64	-6.33	-3.99	-4.39	-3.97	-5.82	-1.00	-3.57	4.90	5.01	3.00	4.76	11.72	6.53	21.90	0.87
81 - 100	-8.21	-4.69	-7.39	-7.83	-5.17	-3.14	-1.07	0.11	1.76	-0.37	10.49	17.56	12.61	14.80	27.15	4.90
101 - 120	4.24	-0.22	-3.80	-2.95	1.87	-4.37	-5.45	2.49	-0.79	6.34	4.72	10.96	6.50	16.17	26.15	4.86
121 - 140	0.00	5.89	-8.14	-4.18	-4.23	-3.27	-6.56	10.47	1.46	-0.37	1.66	8.81	16.52	21.16	35.13	6.55
141 - 160	3.20	-17.94	-6.26	6.18	1.29	-6.78	-3.07	-3.02	-6.64	11.78	12.34	26.70	-13.86	34.64	24.96	4.56
> 160	1.27	-6.96	-2.17	-11.47	3.04	12.95	6.68	10.58	8.18	6.74	45.80	3.27	2.75	22.09	4.15	5.70
total	-10.34	-10.55	-8.98	-7.40	-5.90	-5.34	-3.22	-1.63	0.73	1.95	5.20	10.59	6.99	10.77	25.58	-1.72

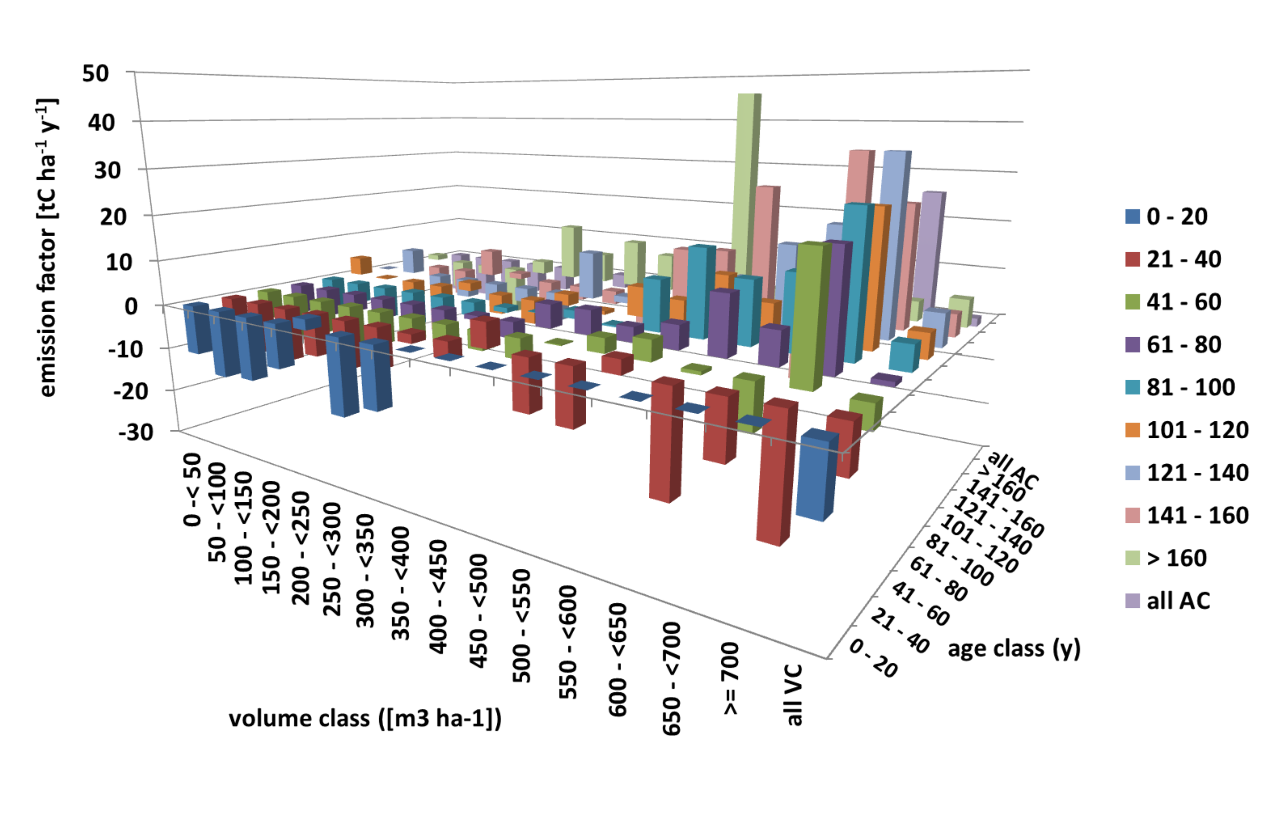

Figure I – 1: EFs [t CO_2-eq. ha^{-1} a^{-1}] during the RP by forest classes, living biomass (trees, above- and belowground, rounded values)

The EF per area unit (ha) for a single class is calculated from repeatedly measured NFI data. The reference period (2000 – 2009) contains two inventories (2002 and 2008). To exclude influences from outside the RP, the EF for the RP is thus calculated as the change in carbon stocks per hectare in the respective stratum (area of the volume and age classes) from 2002 to 2008 (NFI 2002 to Inventory Study 2008). From the same inventories, changes in the area of the respective age class – volume class strata as also the transition probabilities of a unit of area from one class into any other can be estimated (Figure I – 2). In every case, only inventory plots that are located in the 8km by 8km grid used for GHG reporting were used to assure consistency with the GHG Inventory. Combined with the distribution of the strata's areas, the overall emission can be calculated as well as an average EF which takes into account the strata's distribution at a given time. For the RP, the weighted average EF was -1.7 t CO2-eq. ha^{-1} a^{-1}, which is identical to the mean EF reported in the NIR for this period (Table 4 A I). The removals due to harvest or other losses can be derived in these strata, too (see Table I-66). The total net emissions during the Compliance Period are then estimated by multiplying the average EF by the total area of forest land remaining forest land plus the land area moving from "land converted to forest land" (afforestation) after a 20 year transition period in each year of the CP, taken from the most recent GHG Inventory (see NIR 2019, table 385). This is in line with the GHG inventory and reporting under the Convention. For comparison, the net emissions in the respective age class / volume class strata are given in Table I-.

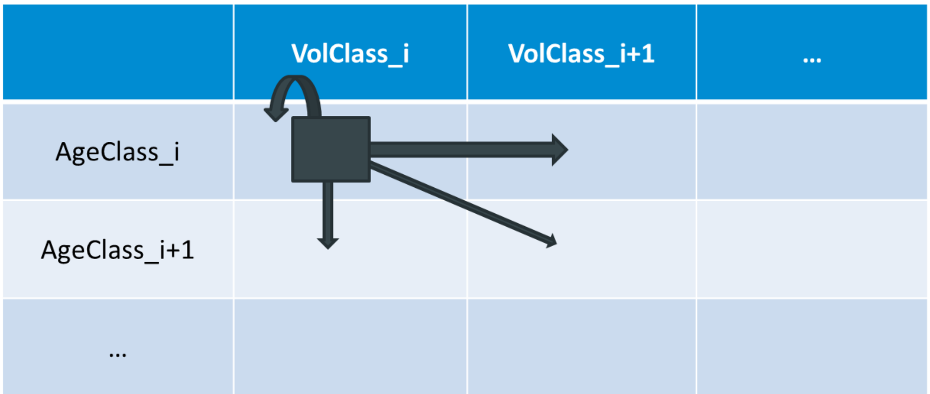

Figure I – 2: Visualisation of transition vectors in the age class – volume class matrix

This approach does not cover the RP in total and was thus questioned by the Commission, who wanted net emissions reported for the years of the RP not covered by the consecutive inventories to be included in the assessment. Since these emissions are calculated from changes between inventories out- and inside the RP (first NFI: 1987/1990, second NFI 2012), from Germanys perspective, including these data violated the core conditions laid out in the Regulation and further explained in Forsell et al. (2018).

In consultations with Germany it was decided to adjust net emissions from living biomass to reflect the full reference period, using a correction factor based on emission factors estimated by the logging factor method as described by Roehling et al. (2016)[2]. This method provides annual emission factors by using the periodical averages of stock changes in GHG reporting as a basis, but modulating these with annual harvest data. This can be interpreted as a surrogate method described in IPCC guidelines. The method was applied using updated data on harvest, which are consistent with the data as referenced in the GHG inventory (referenced there as http://faostat3.fao.org/home/E). The same harvest data also serve for the proportional adjustment of the HWP inflow (see section 3.4 Adjustments for HWP).

Table I - 4 shows the emission factors used in this recalculation of the German FRL, and the underlying harvest data. The ratio for emission factors was used to correct for the reference period for living biomass (section 3.5); the ratio for harvests for the adjustment in the HWP pool (section 3.4).

[2] Röhling, S., K. Dunger, G. Kändler, S. Klatt, T. Riedel, W. Stümer and J. Brötz (2016). "Comparison of calculation methods for estimating annual carbon stock change in German forests under forest management in the German greenhouse gas inventory." Carbon Balance and Management 11(1): 12.

Table I – 4: Emission factors for the reference period as used in the recalculated German FRL, and the underlying harvest data.

Year	EF (using Roehling et al. (2016) logging factor method) [t C ha^{-1} yr^{-1}]	Annual harvest based on Faostat, calibrated with German NFI) [m^3 o.b.]
2000	0.955	123,671,605
2001	1.458	91,004,951
2002	0.460	97,831,353
2003	0.490	90,504,077
2004	0.466	96,432,663
2005	0.448	100,864,165
2006	0.410	110,228,980
2007	0.306	135,610,116
2008	0.990	101,297,196
2009	1.131	87,937,665
Average 2002-2007	0.430	105,245,226
Average 2000-2009	0.711	103,538,277
Ratio between both averages	**1.655**	**0.984**

I.3 Area of Managed Forest Land (MFL)

The German NFAP used most recent data directly from the National Greenhouse Gas Inventory, while the Commission argued for using data from the 2019 GHG Inventory submission (i.e., data for 2017). The data used for the NFAP had thus partly to be "rolled back" to an older state, what would have had no implications for accounting purposes. The area of managed forest land, what corresponds to the area of "forest land remaining forest land" in the German National Inventory Report, and the afforested areas that are added to the managed forest land 20 years after afforestation, are shown in table I – 5. Deforestation is set to zero. The table shows the Commission's estimate of managed forest land area in the compliance period 2021-2025. The area of "forest land remaining forest land" in 2017 was taken as starting point from the GHGI 2019. For

2018 to 2025 the area entering the scope of managed forest land area[3] was added. The yearly values of the period 2021-2025 were used to estimate emissions and removals from living biomass. For simplicity with regards to other recalculations, emissions and removals of all other pools and gases were estimated with the average area of the reference period (10,607,070 ha); emissions and removals for HWP are independent of area.

Table I -5. Area of managed forest land for living biomass.

Year	Area afforested 20 years ago [ha]	Area of managed forest land per year [ha]
2017		10,832,447
2018	27,619	10,860,066
2019	27,619	10,887,685
2020	27,619	10,915,304
2021	15,350	10,930,654
2022	15,350	10,946,004
2023	15,350	10,961,354
2024	15,350	10,976,704
2025	15,350	10,992,055

[3] Area entering the scope of managed forest land is defined here, in line with the German NFAP as: "land converted to forest land" 20 years ago and zero deforestation. In practice: area entering managed forest land in 2018 is "land converted to forest land" in 1998.

Table I-6: Harvest as loss of timber [Mio. reserve solid cubic metres (RSCM) a-1] from final felling or thinning during the RP by stratum derived from forest inventory information

	volume class [m^3 ha^{-1}]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	0.15	0.28	0.23	0.17	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90
21 - 40	0.09	0.43	1.07	1.50	1.81	1.94	1.75	1.44	1.93	0.30	0.49	0.20	0.11	0.21	0.02	13.30
41 - 60	0.04	0.18	0.59	1.08	1.70	2.30	3.22	2.55	2.02	2.48	1.47	1.08	0.54	0.48	1.75	21.47
61 - 80	0.00	0.11	0.37	0.89	1.13	1.10	1.49	1.77	2.12	2.28	1.49	1.73	1.29	0.70	4.06	20.52
81 - 100	0.02	0.08	0.18	0.23	0.53	1.07	1.53	1.23	1.95	1.37	2.35	2.23	1.50	1.71	7.37	23.35
101 - 120	0.01	0.10	0.13	0.27	0.73	0.56	0.70	1.05	1.14	1.54	1.04	1.24	0.65	1.10	4.48	14.76
121 - 140		0.04	0.04	0.16	0.14	0.33	0.43	0.49	0.76	0.49	0.57	0.59	0.83	0.71	2.83	8.40
141 - 160	0.01	0.00	0.08	0.05	0.19	0.13	0.15	0.10	0.16	0.23	0.31	0.60	0.05	0.25	0.59	2.91
> 160				0.02	0.09	0.13	0.09	0.06	0.09	0.07	0.17	0.05	0.14	0.19	0.18	1.30
total	0.32	1.21	2.71	4.38	6.41	7.55	9.36	8.69	10.18	8.75	7.89	7.72	5.11	5.35	21.28	106.91

Table I-7: Total net emissions [Mt CO2-eq. a-1] during the RP by forest classes, living biomass (trees, above- and belowground, rounded values, corrected)

	volume class [m³ ha⁻¹]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	-9.52	-2.07	-1.15	-0.26	0.01	-0.03	-0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-13.04
21 - 40	-1.05	-2.85	-3.11	-2.34	-2.39	-1.78	-0.20	-0.35	0.42	-0.29	-0.31	0.02	-0.23	-0.16	-0.11	-14.72
41 - 60	-0.30	-0.91	-1.33	-2.01	-2.02	-1.38	-1.53	-0.83	-0.74	0.03	0.20	0.20	-0.03	-0.28	1.06	-9.85
61 - 80	-0.10	-0.36	-0.34	-0.67	-0.69	-0.98	-0.19	-0.67	0.72	0.68	0.29	0.44	0.69	0.24	2.42	1.49
81 - 100	-0.12	-0.11	-0.45	-0.61	-0.60	-0.54	-0.16	0.01	0.27	-0.05	1.31	1.63	0.79	0.92	5.34	7.63
101 - 120	0.01	-0.01	-0.13	-0.15	0.15	-0.47	-0.58	0.23	-0.09	0.58	0.37	0.74	0.35	0.72	3.52	5.25
121 - 140	0.00	0.03	-0.17	-0.14	-0.11	-0.15	-0.39	0.39	0.08	-0.02	0.07	0.30	0.53	0.54	2.59	3.55
141 - 160	0.01	-0.09	-0.09	0.07	0.02	-0.13	-0.08	-0.10	-0.19	0.17	0.28	0.60	-0.16	0.33	0.60	1.24
> 160	0.01	-0.02	-0.02	-0.13	0.05	0.13	0.06	0.05	0.08	0.05	0.22	0.03	0.04	0.18	0.06	0.77
Total	-11.05	-6.39	-6.78	-6.24	-5.57	-5.32	-3.09	-1.27	0.55	1.15	2.44	3.95	1.99	2.50	15.48	-17.66

I.4 Application of emission factors for the compliance period to reproduce historical management

The RP is set as 2000-2009 by the Regulation. The CPs are 2021-2025 and 2026-2030. In the time between the RP and the first CP forests are changing due to dynamic age-related factors (forest characteristics, area distribution of classes) and possible changes in forest management practices. For accounting in the CP, the stock differences calculated from the (forest) inventories 2017, 2022, (2027(tbd)) and 2032 will be compared to the FRL. For construction of the FRL (consistent with the stock-difference approach of the German GHG Inventory) the situation at the beginning of the CP was taken into account by using the forest area distribution by strata modelled since 2008, using the transition vectors[4] determined during the RP, and replicated until 2017, the reference year of the last inventory prior to the CP and representative for the starting conditions of the first CP. This way, the FRL and the inventory to estimate the real development of the forest were considered to have the same starting point in time and possible weighing effects due to non-parallel periods are avoided. The resulting distribution of age class / volume class strata is given in Table I-83 . Simulating the conditions at the starting point of the CP in this way should exclude the effects of changes in management between the RP and the CP. Changes of the age class / volume class strata during this period should be addressed by the transition vectors. However, since all years from the RP irrespective of the timing of the related inventories had to be included, and non-parallel periods were not considered problematic, the projection of the area distribution was prolonged to 2022 (Table I – 9) and the net emissions from living biomass for the first CP were calculated as the weighted average of the simulated emissions of the periods 2017 – 2022 and 2022 – 2027. For 2017 – 2022, the emission factor was -0.655 t CO_2 ha^{-1} yr^{-1}, and for 2023 – 2027 it was -0.453 t CO_2 ha^{-1} yr^{-1}. Using the area estimates as described above and applying the correction factor for RP years outside of the inventory cycle resulted in annual net emissions of -9,680,607 t CO_2e yr^{-1} (living biomass).

[4] i.e. the transition probability of a unit of area located in a specific age class – volume class combination to remain in this class during the RP or moving to any other specific class.

Table I-83: Area [kha] distribution of forests classes at beginning of the CP (simulated distribution 2017, more digits shown than in submitted NFAP)

	volume class [m³ ha-1]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	716.973	100.443	58.048	29.842	14.985	6.247	1.344	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	927.881
21 - 40	123.048	195.528	176.929	173.180	149.676	113.258	83.827	78.477	36.510	25.927	19.174	10.583	6.624	3.739	2.364	1,198.844
41 - 60	45.425	111.770	139.334	236.325	206.863	258.160	222.592	189.961	156.972	139.043	105.356	77.853	62.418	34.840	92.796	2,079.707
61 - 80	55.545	43.115	107.794	139.116	179.017	173.000	174.181	209.575	178.042	115.051	83.288	85.996	84.653	49.373	116.261	1,794.006
81 - 100	24.081	31.456	76.016	81.829	142.696	142.077	192.004	158.295	161.039	114.313	113.497	98.502	80.739	49.946	168.802	1,635.291
101 - 120	9.838	18.341	39.850	55.928	121.014	120.493	134.889	150.616	116.040	103.735	106.790	64.538	70.233	59.756	143.626	1,315.686
121 - 140	0.000	16.611	30.817	42.070	32.972	40.619	83.843	67.309	75.128	78.830	62.055	42.601	40.152	33.453	75.966	722.427
141 - 160	0.000	3.070	12.589	16.708	27.401	15.399	20.993	28.216	48.398	37.272	21.293	29.571	19.860	7.520	50.297	338.589
> 160	6.369	16.197	22.167	23.368	17.214	18.507	14.062	31.985	22.290	6.972	7.362	18.391	7.459	7.018	31.196	250.558
total	981.280	536.530	663.544	798.367	891.838	887.761	927.736	914.433	794.419	621.143	518.815	428.036	372.137	245.645	681.307	10,262.990

Table I - 9: Area [kha] distribution of age and volume classes at the end of step 4 (2022)

	volume class [m³ ha-1]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	717.125	99.599	57.150	28.927	14.535	6.085	1.325	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	924.746
21 - 40	121.115	189.815	168.898	163.050	139.677	104.098	75.749	70.574	32.526	23.120	16.932	9.387	5.824	3.259	2.092	1,126.114
41 - 60	44.316	110.878	133.890	223.121	193.430	238.149	205.177	175.122	145.603	128.854	99.360	72.960	60.326	34.163	91.579	1,956.929
61 - 80	58.303	44.556	107.765	138.941	176.000	168.906	169.854	204.883	174.758	113.402	82.666	85.516	84.985	50.028	121.329	1,781.892
81 - 100	26.596	32.664	78.301	84.021	146.636	145.139	196.069	160.455	163.292	115.678	115.202	100.011	82.974	50.996	173.351	1,671.383
101 - 120	10.656	19.152	42.098	58.297	125.967	126.199	140.796	157.116	121.957	107.992	110.971	66.650	72.268	61.502	145.789	1,367.410
121 - 140	0.000	17.398	32.705	44.607	35.263	43.561	89.547	72.234	81.340	84.397	66.943	46.084	43.105	35.413	78.630	771.227
141 - 160	0.000	3.268	13.526	17.959	29.568	16.669	22.718	30.581	53.004	40.795	23.464	32.412	21.686	8.213	55.299	369.162
> 160	6.369	18.889	26.274	28.453	20.533	22.374	16.969	39.685	25.604	7.429	8.059	20.457	8.427	8.034	36.570	294.128
total	984.481	536.220	660.608	787.376	881.609	871.179	918.204	910.650	798.084	621.667	523.596	433.476	379.595	251.607	704.639	10,262.990

Table I-10: Harvest as loss of timber [Mio. reserve solid cubic metres (RSCM) a^{-1}] from final felling or thinning during the CP by stratum

	volume class [m^3 ha^{-1}]															
age class [y]	**0 - <50**	**<= 50 - <100**	**<= 100 - <150**	**<= 150 - <200**	**<= 200 - <250**	**<= 250 - <300**	**<= 300 - <350**	**<= 350 - <400**	**<= 400 - <450**	**<= 450 - <500**	**<= 500 - <550**	**<= 550 - <600**	**<= 600 - <650**	**<= 650 - <700**	**<= 700**	**all classes**
0 - 20	0.12	0.20	0.16	0.19	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
21 - 40	0.10	0.33	0.71	1.01	1.20	1.11	1.41	1.18	0.87	0.28	0.35	0.34	0.06	0.05	0.01	9.01
41 - 60	0.04	0.23	0.46	1.14	1.23	2.16	2.31	2.33	1.86	2.48	2.26	1.70	0.81	0.54	3.49	23.05
61 - 80	0.02	0.08	0.47	0.81	1.16	1.13	1.37	1.97	2.56	1.93	1.28	1.60	1.84	0.94	4.26	21.42
81 - 100	0.03	0.10	0.23	0.24	0.66	0.88	1.91	1.60	2.07	1.24	2.13	2.36	1.94	1.38	6.32	23.09
101 - 120	0.07	0.06	0.16	0.31	1.11	0.63	0.89	1.75	1.22	1.74	1.42	1.19	0.84	1.47	4.78	17.62
121 - 140	0.00	0.13	0.06	0.20	0.18	0.29	0.61	0.90	1.06	0.75	0.79	0.74	1.03	0.93	2.91	10.58
141 - 160	0.00	0.00	0.07	0.08	0.30	0.10	0.12	0.08	0.27	0.60	0.30	0.79	0.09	0.19	1.25	4.24
> 160	0.00	0.00	0.00	0.04	0.10	0.25	0.14	0.38	0.22	0.06	0.26	0.11	0.08	0.17	0.39	2.21
Total	0.38	1.13	2.32	4.02	6.11	6.55	8.75	10.19	10.12	9.08	8.77	8.83	6.70	5.68	23.42	112.06

This distribution of forest area into the strata (Table I-83) takes account of the age class-related changes between the reference period and the commitment period. It is combined with the historical EFs per class (Table I-3) in order to derive a new weighted average EF or the expected (reference) emission for the CP for the above- and belowground living biomass pools.

I.5 Summary

The approach described above proposes the calculation of the living biomass part of the FRL by using the "alternative approach" as explained in Box 12 of Forsell et al. (2018).

It maps the historical forest development and therefore the historical forest net emissions/removals resulting from this during the reference period into the compliance period using differentiated emission factors by forest classes. These are used as proxy to reflect the impact of forest management to a defined class of forests. This approach exactly reproduces the respective historical GHG Inventory of the RP. If parameterized with the data from any subsequent inventories, the algorithm is capable of reproducing any historical period for which these data are available. The compatibility of the FRL and historical GHG Inventories is thus ensured.

National Forest Accounting Plan for Germany – Annex II

Modelling framework for projecting the Forest Reference Level

Part II: Litter and soil

This part received the largest changes during the recalculation, as the approach was completely revised. At the time of the first submission it was intended to change the method of soil organic matter reporting in the NGHGI to a model-based, higher tier approach. Since this had not been completed in the NIR 2019, to ensure coherence with the NIR, this had to be omitted. Instead, average net emissions and removals for the reference period (2000-2009) from the GHG inventory 2019 were used, assuming that the area of managed forest land remains constant between reference period and compliance period. These emissions include emissions from CRF table 4(II) for “forest land”, which are assumed to occur entirely on “Managed Forest land”. In case the change to the model-based reporting will be conducted in the future, a technical correction of the FRL must be applied. Part II is thus given here for explanatory reasons only.

II.1 Background

For forest lands, mineral and organic soils are treated differently. For mineral soils, the projection of litter and soil carbon pools and related net emissions is based on findings from Ziche et al. (2019). In this study, a soil model (YASSO15) was used to project carbon stocks based on data from two National Forest Soil Inventories (NFSI), and in case of litter fall on Intensive Forest Monitoring plots (Level II).

The 1st NFSI was conducted between 1987 and 1994 with over 1900 sample plots distributed in an 8km by 8km grid throughout Germany. In appr. 65% of the samples, mineral soil was taken to a depth of 90cm, while – due to solid bedrock – in 10% of cases the sampling depth was only 60cm, and only down to 30cm in the remaining appr. 25%. In the 2nd NFSI ca. 1,300 plots were re-sampled and appr. 600 plots were replaced. Stand characteristics of the surrounding forests were only sampled in the 2nd NFSI.

For organic soils, which are not included in the NFSI estimates, the emission factors for the RP are taken from the NIR 2018 (net CO_2-emissions from organic soils, N2O and CH4-emissions as CO_2-equivalent) and the average value from the RP is applied as part of the FRL. The same approach is applied for emissions from forest fires.

II.2 Modelling

The projected soil and litter carbon stocks were taken from Ziche et al. (2019). In this study, YASSO15 was used for projecting soil carbon and litter based on the German NFSI findings and climate data (measured data from the German Weather Office (DWD) for 1961 – 2014, regionalized ECHAM6 data for 2014 – 2030, see Ziche et al. (2019) for details). Litter input from living trees was assumed to be constant over the projection period, while input from management activities and natural mortality was simulated based on the stand inventories, harvest ratios, and timber assortment structure from data till 2014. For the projection, the average input per plot from 2009 – 2013 was used in this study. This is a deviation from the RP set by the Regulation, but this study was not intended as part of the FRL construction and other, better data are not available. The differences in litter fall between this period and the RP are small, as far as the factors that determine litter fall are concerned.

II.3 Reproduction of historical data

The modelled carbon balance (0.25 ± 0.10 Mg C ha^{-1} a^{-1}) was lower than the measured value of the NFSI (0.39 ± 0.11 Mg C ha^{-1} a^{-1}) (Grüneberg et al. 2014) for the organic layer and mineral soil down to a depth of 30 cm (Ziche et al. 2019). The values are within their reciprocal confidence intervals and the difference between these average values is not statistically significant, so the modelled values can be used in construction of the FRL without any e.g. 'calibration' or further alteration.

II.4 Stratification of managed forest land

The simulations of litter and soil (to a depth of 90cm) were conducted on the level of the single inventory plot and then aggregated according to the soil stratification used in the GHG inventory and reporting (see NIR 2018 for details) and by 22 forest types (to reflect differences in litter input).

II.5 Projected net emissions from soil and litter

The projections resulted in mean annual net emissions as shown in Table II-1.

Table II-1: Projected net emissions from the soil and litter pools [Mio. t CO2-eq. a-1] during the CP

	Unit	2021 - 2025	COM recalculation
Mineral soil and litter	[Mio. t CO_2 a^{-1}]	3.874	-15.309647
Organic soils	[Mio. t CO_2-eq. a^{-1}]	2.847	0.912138
Total	**[Mio. t CO_2-eq. a^{-1}]**	**6.721**	**14.397509**

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