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National Forestry Accounting Plan for Germany

J.Rock, K. Dunger, P. Hennig, S. Rüter, W. Stümer, F. Schmitz

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Dr. Joachim Rock
Karsten Dunger
Petra Hennig
Dr. Wolfgang Stümer
Thünen Institute of Forest Ecosystems, Eberswalde

Dr. Sebastian Rüter
Thünen Institute of Wood Research, Hamburg

Friedrich Schmitz, Bundesministerium für Ernährung und Landwirtschaft

Jasper Braam, Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit

Johann Heinrich von Thünen-Institute
Bundesforschungsinstitut für Ländliche Räume, Wald und Fischerei
Bundesallee 50
38116 Braunschweig
Germany

Tel.: **+49 3334 3820 351**
Fax: **+49 3334 3820 354**
E-Mail: joachim.rock@thuenen.de

Content

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.

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 a stock change approach and relies on the development of the carbon content in each forest stratum (i.e. tree age, volume class) in the reference period. The development of the carbon content is used as a proxy for the management practices. These vectors 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 2017 in order to take into account the age-related forest characteristics. 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. A detailed description of the modelling approach can be found in Annex I.

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 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). As reported for the greenhouse gas emissions assessment in 2016, Germany's stocked forest land covers appr. 10.8 million hectares and is completely reported under the Convention in the respective land use category "Forest Land remaining Forest

Land". 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 focussing 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.

Forests also play an important role in Germany's National Strategy on Biological Diversity (2007). In the strategy it is envisioned that "forests in Germany have a high level of natural diversity and momentum in terms of their structure and species composition, and people are fascinated by their beauty. The number of natural and near-natural forest communities has increased significantly. Forests are sustainably managed in line with their ecological and social functions. The raw material wood obtained sustainably from the forests is highly valued." The aims for the year 2020 are that "the conditions for typical biotic communities in forests (diversity in structure and momentum) have been further improved. The trees and bushes of

the natural forest community have been completely rejuvenated, primarily via natural means. Semi-natural management forms use natural processes to strengthen the ecological functions. Old and dead wood is available in sufficient quantity and quality. By 2020, forests with natural forest development account for 5 % of the wooded area. When establishing new forests, there is a growing trend in favour of using native tree species. The proportion of non-native tree species is being continually reduced. Historical forest usage forms such as coppice-with-standards forest, simple coppice forest and grazing-forest, with their high potential for nature conservation or recreation, will be continued and, where possible, expanded."

Another instrument for promoting biological diversity in forests is contractual nature conservation. To this end, the National Strategy on Biological Diversity includes the objective of promoting contractual nature conservation in private forests on ten percent of the area. This is aimed at private forest owners, who own around 48 percent of the forest in Germany.

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 they are not 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 wood harvested 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 amount of harvested wood is used to estimate the changes in the HWP pool with the model WoodCarbonMonitor (Rüter 2017). Emissions from changes in the dead wood pool and from forest fires were assumed to be equal to the mean from the RP, respectively. The development of the litter pool is modelled together with soil carbon in Yasso15 (for details, see Ziche et al. 2019). 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). 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. 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.

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 harvested wood products (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.

The projected harvest amounts as loss of timber derived from forest inventory information are given with the description of the forest management modelling in Annex I.

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 litter pool was simulated, together with the soil carbon pool of mineral soils, with YASSO15, and projections for net emissions from organic soils and dead wood were added (see Annex II for details).

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

The aggregated FRL for Germany is estimated to be net emissions of -10.0224 million tons CO_2-equivalent per year in the first Compliance Period 2021 – 2025. The contribution of the individual pools considered here are given in Table 2. Net emissions from the respective pools from the RP are given for comparison.

Table 2: Annual net emissions from different pools (Mio. t CO_2-eq. a^{-1})

Pool	2021 - 2025
Living biomass	-7.0850
Soil (including litter)	6.7205
dead wood	- 1.0810
Forest fires	0.0300
Sum (without HWP)	-1.4154
HWP	-8.6070
Sum	-10.0224

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 Forestry 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). 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-2, 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

age class [y]	volume class [m³ ha⁻¹]															
	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	865.9	140.6	83.1	27.2	6.4	1.6	1.6	0	0	0	0	0	0	0	0	1,126.4
21 - 40	117.8	255.0	266.8	256.8	226.8	198.2	103.9	95.7	81.4	27.3	27.1	6.4	11.1	14.4	4.8	1,693.7
41 - 60	46.4	86.6	181.9	223.4	284.2	274.6	309.9	207.9	171.0	139.1	68.6	49.5	41.6	30.5	46.4	2,161.6
61 - 80	14.4	57.5	85.0	153.3	174.3	167.9	188.8	188.6	147.0	136.0	97.4	92.8	59.2	36.9	110.7	1,709.6
81 – 100	14.3	24.0	60.8	78.5	115.4	172.3	153.8	121.3	152.0	126.2	125.2	92.9	62.3	62.2	196.7	1,558.1
101 - 120	1.6	30.4	33.7	49.5	80.2	107.4	106.9	90.9	108.8	91.5	78.4	67.3	54.6	44.8	134.7	1,080.8
121 - 140		4.8	20.8	33.7	25.6	46.3	59.2	36.8	54.2	51.1	44.7	33.8	32.1	25.5	73.8	542.5
141 - 160	3.3	6.4	14.4	11.1	17.6	19.2	27.2	33.4	28.7	14.4	22.4	22.5	11.2	9.6	23.9	265.3
> 160	6.4	3.2	9.6	11.2	15.9	9.7	9.6	4.8	9.5	8.0	4.8	8.0	12.8	8.0	14.4	135.9
total	1,070.1	608.7	756.1	844.8	946.2	997.1	960.9	779.6	752.7	593.6	468.6	373.0	284.9	232.0	605.4	10,273.9

Table I-2: EFs [t CO_2-eq.ha^{-1} a^{-1}] during the RP by forest classes, living biomass (trees, above- and belowground, rounded values)

| age class [y]	volume class [m³ ha^{-1}]															
	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	-11.0	-14.8	-13.9	-9.7	2.2	-16.3	-13.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-11.6
21 - 40	-8.9	-11.2	-11.7	-9.1	-10.6	-9.0	-1.9	-3.6	5.2	-10.7	-11.5	2.8	-20.3	-11.2	-22.4	-8.7
41 - 60	-6.4	-10.5	-7.3	-9.0	-7.1	-5.0	-4.9	-4.0	-4.3	0.2	2.9	4.1	-0.7	-9.1	22.8	-4.6
61 - 80	-6.6	-6.3	-4.0	-4.4	-4.0	-5.8	-1.0	-3.6	4.9	5.0	3.0	4.8	11.7	6.5	21.9	0.9
81 - 100	-8.2	-4.7	-7.4	-7.8	-5.2	-3.1	-1.1	0.1	1.8	-0.4	10.5	17.6	12.6	14.8	27.2	4.9
101 - 120	4.2	-0.2	-3.8	-2.9	1.9	-4.4	-5.5	2.5	-0.8	6.3	4.7	11.0	6.5	16.2	26.2	4.9
121 - 140	0.0	5.9	-8.1	-4.2	-4.2	-3.3	-6.6	10.5	1.5	-0.4	1.7	8.8	16.5	21.2	35.2	6.6
141 - 160	3.2	-18.0	-6.3	6.2	1.3	-6.8	-3.1	-3.0	-6.6	11.8	12.3	26.7	-13.9	34.7	25.0	4.6
> 160	1.3	-7.0	-2.2	-11.5	3.0	13.0	6.7	10.6	8.2	6.7	45.8	3.3	2.8	22.1	4.2	5.7
total	-10.3	-10.6	-9.0	-7.4	-5.9	-5.3	-3.2	-1.6	0.7	1.9	5.2	10.6	7.0	10.8	25.6	-1.7
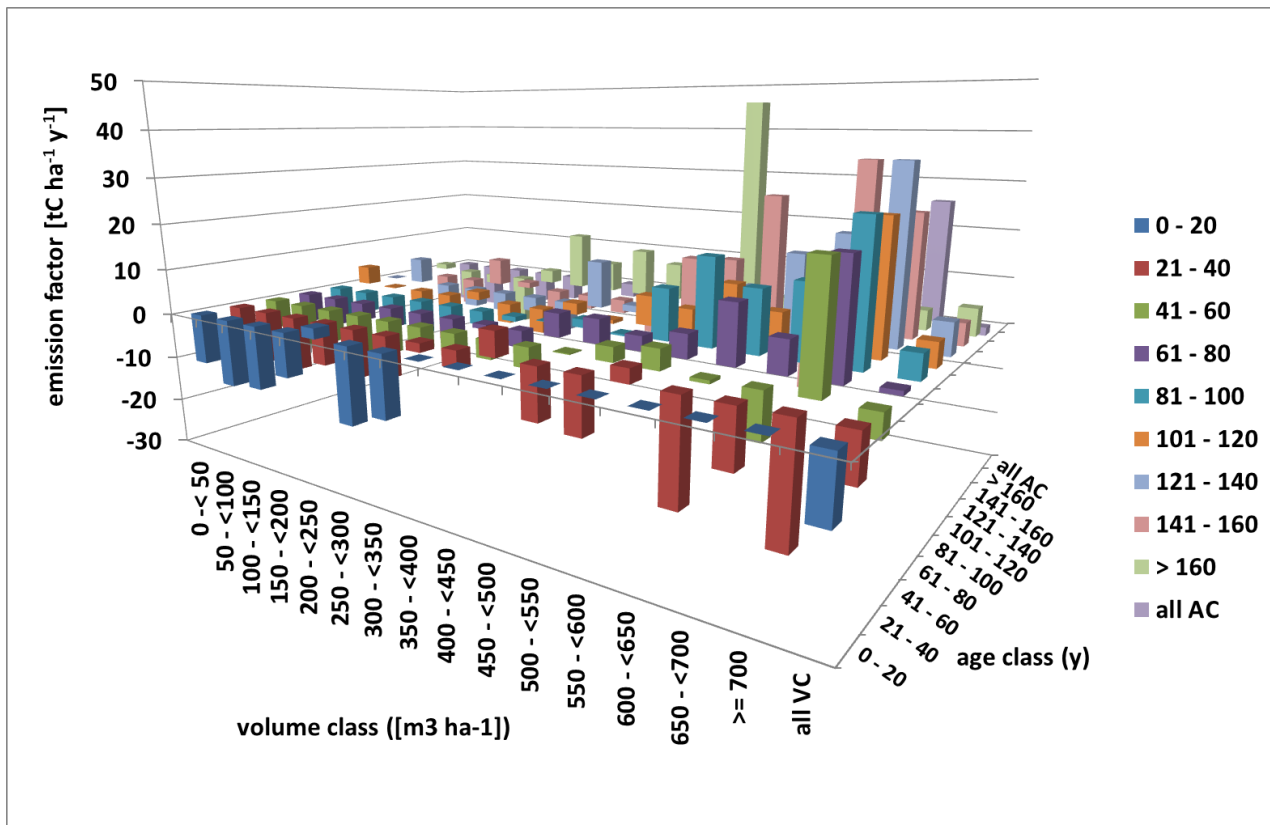
Figure I – 1: EFs [t CO_2-eq.ha^{-1} a^{-1}] during the RP by forest classes, living biomass (trees, above- and belowground, rounded values)

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. 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-3). 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-4.

Table I-3: 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

age class [y]	volume class [m³ ha^{-1}]															all classes
	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	
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-4: Total net emissions [Mt CO_2-eq. a^{-1}] during the RP by forest classes, living biomass (trees, above- and belowground, rounded values)

age class [y]	volume class [m³ ha^{-1}] 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	-10.47	-2.17	-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	-14.12
21 - 40	-1.08	-2.92	-3.17	-2.40	-2.43	-1.85	-0.21	-0.35	0.43	-0.29	-0.31	0.02	-0.23	-0.16	-0.11	-15.09
41 - 60	-0.30	-0.91	-1.36	-2.02	-2.04	-1.38	-1.55	-0.84	-0.74	0.03	0.20	0.21	-0.03	-0.28	1.09	-9.96
61 - 80	-0.10	-0.37	-0.34	-0.68	-0.70	-0.98	-0.19	-0.68	0.73	0.69	0.30	0.44	0.69	0.25	2.42	1.50
81 - 100	-0.12	-0.11	-0.46	-0.63	-0.60	-0.54	-0.17	0.01	0.27	-0.05	1.31	1.63	0.79	0.92	5.43	7.74
101 - 120	0.01	-0.01	-0.13	-0.15	0.16	-0.47	-0.58	0.23	-0.09	0.58	0.38	0.75	0.35	0.73	3.57	5.31
121 - 140		0.03	-0.17	-0.14	-0.11	-0.15	-0.39	0.39	0.08	-0.02	0.08	0.30	0.53	0.54	2.77	3.62
141 - 160	0.01	-0.12	-0.09	0.08	0.02	-0.14	-0.08	-0.11	-0.19	0.17	0.28	0.60	-0.16	0.39	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	-11.98	-6.59	-6.90	-6.35	-5.66	-5.38	-3.13	-1.29	0.55	1.18	2.47	3.99	2.00	2.53	15.78	-18.08

I.3 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(?)) 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 is taken into account by using the forest area distribution by strata modelled since 2008, using the transition vectors[1] 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 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-5. 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.

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[1] The transition vectors show 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-5: Area [kha] distribution of forests classes at beginning of the CP (simulated distribution 2017)

age class [y]	volume class [m³ ha⁻¹]															
	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	717.0	100.4	58.0	29.8	15.0	6.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	927.9.
21 - 40	123.0	195.5	176.9	173.2	149.7	113.3	83.8	78.5	36.5	25.9	19.2	10.6	6.6	3.7	2.4	1198.8.
41 - 60	45.4	111.8	139.3	236.3	206.9	258.2	222.6	190.0	157.0	139.0	105.4	77.9	62.4	34.8	92.8	2079.7.
61 - 80	55.5	43.1	107.8	139.1	179.0	173.0	174.2	209.6	178.0	115.1	83.3	86.0	84.7	49.4	116.3	1794.0.
81 - 100	24.1	31.5	76.0	81.8	142.7	142.1	192.0	158.3	161.0	114.3	113.5	98.5	80.7	49.9	168.8	1635.3.
101 - 120	9.8	18.3	39.9	55.9	121.0	120.5	134.9	150.6	116.0	103.7	106.8	64.5	70.2	59.8	143.6	1315.7.
121 - 140	0.0	16.6	30.8	42.1	33.0	40.6	83.8	67.3	75.1	78.8	62.1	42.6	40.2	33.5	76.0	722.4
141 - 160	0.0	3.1	12.6	16.7	27.4	15.4	21.0	28.2	48.4	37.3	21.3	29.6	19.9	7.5	50.3	338.6
> 160	6.4	16.2	22.2	23.4	17.2	18.5	14.1	32.0	22.3	7.0	7.4	18.4	7.5	7.0	31.2	250.6
total	981.3.	536.5	663.5	798.4	891.8.	887.8	927.7	914.4	794.4	621.1	518.8	428.0	372.1	245.6	681.3	10263.0.

Table I-6: Harvest as loss of timiber [Mio. reserve solid cubic metres (RSCM) a^{-1}] from final felling or thinning during the CP by stratum

age class [y]	volume class [m³ ha^{-1}]															all classes
	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	
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-5) is taking into account the age class-related changes between the reference period and the commitment period. It is combined with the historical EFs per class (Table I-2) 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. For the first CP, the modelled average annual net emissions from the living biomass pool are -7.085 Mio t CO_2-eq.

For HWP, 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-3) during the RP weighed by the area in each stratum at the start of the CP (using the closest simulated inventory prior to the CP – Table I-5). This leads to an adjusted overall harvest as loss of timber (in reserve solid cubic metres, RSCM) within the CP (Table I-6). 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-3. 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 1-6). 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 as described in Section 3.1.

I.4 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 Forestry Accounting Plan for Germany – Annex II

Modelling framework for projecting the Forest Reference Level

Part II: Litter and soil

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 CO$_2$-eq. a^{-1}] during the CP

	Unit	2021 - 2025
Mineral soil and litter	[Mio. t CO$_2$ a^{-1}]	3.874
Organic soils	[Mio. t CO$_2$-eq. a^{-1}]	2.847
Total	**[Mio. t CO$_2$-eq. a^{-1}]**	**6.721**

References

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